ELEMENTARY SCIENCE

BOOK II

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INTRODUCTION

It is essential that science should be taught to all pupils in schools. There are two reasons for this necessity. Science is part of culture; without some elementary knowledge of science we can have no conception of what we are, how we came into being, and what the world around us is. And secondly, our civilisation is founded so largely on science; agriculture, engineering and hygiene, all demand scientific knowledge, both to understand them and to practise them.

Science is the youngest subject in the school curriculum and until recently it has not received the attention which its importance demands. Moreover, in so many instances a part only of science has been taught, often physics or chemistry to boys, botany to girls. This book is the second of a series of three, which give a balanced elementary account of science, physical and biological. I believe that these books will be a real help both to teachers and pupils. For the former they outline a suitable course of teaching, obviating much difficult preparatory work in the other branches of science for the teacher who is principally a physicist, a chemist or a biologist. For the pupil the lessons in school will be impressed and made much more interesting by the simply worded accounts given in narrative style.

No really suitable book exists for the purposes outlined above, and, having had the pleasure of collaborating with Mr Webb and Miss Grigg in the preparation of their manuscript, I am convinced that their books will succeed.

H. MUNRO FOX
Professor of Zoology

UNIVERSITY OF BIRMINGHAM
October, 1935

PREFACE

SCIENCE AND THE SCHOOLS

The task of the science specialist in schools is, perhaps, the most difficult of all in the teaching profession. He is, often, a specialist himself in one or two branches of science. The Board of Education quite rightly, however, would like all children to be instructed in the general elementary principles of science as a whole.

If this desire of the Board of Education, and educationists as a body, is to be properly carried out an additional burden of preparation will have to be laid on the shoulders of the science teacher. Already he is responsible for the stock and requisition of material which is often more numerous in the number of items than the rest of the school stock put together.

Furthermore, the great value of science teaching lies in its practical application both in and out of school. In many instances the science teacher has neither a great deal of time for preparation nor a laboratory steward at his disposal. In these cases he finds that he has not sufficient time for the personal supervision that is necessary in the early stages. This lack of time is felt particularly when pupils are allowed to indulge in the delights of individual experimental work.

THE OBJECT

The object of this series of three books is twofold:

1. To stimulate the pupil to take an intelligent, and where possible an active, interest in all that goes on around him.

2. To lighten the burden of the science teacher as much as possible and so enable him to carry out his work in a still more efficient manner.

THE METHOD

Although the methods of teaching science are as numerous as the teachers, in the main the lessons can be divided into four sections. They are:

1. Descriptive and explanatory talk by the teacher together with demonstrations.

As the talk does not require definite personal effort on the part of the pupil it is, sometimes, not as successful as the teacher would like.

2. The writing of a summary of the lesson as notes. These notes represent the "essential minimum" of what the pupil should know in connection with the lesson.

3. Questions.

4. Individual experimental work where possible.

The authors propose to lighten the burden of the science teacher as much as possible by presenting:

(*a*) Interesting and stimulating reading matter.

This will require personal effort from the pupil, and partly replace the talk of the teacher. Consequently the teacher should be a little more free for preparation.

(*b*) Summary.

It will be satisfactory for the pupil to copy the summary directly from the text-book.

(*c*) Questions and exercises.

(*d*) Experiments with simple apparatus giving the stimulus to hobbies.

These experiments are in addition to those appearing under (*a*). *There is no necessity for the teacher to prepare Instruction Cards.*

The matter dealt with is concise, and the scientific phraseology is carefully treated in the earlier stages so that the pupil has every chance of grasping the subject. For example, the pupil commencing the study of science more fully comprehends the phrase "the force with which the air presses" than "the air pressure". Frequent use is made of synonyms and synonymous expressions.

It will be seen that the book is suitable for use in all types of schools in the town or country. The introduction of sections makes the work capable of being adapted to the varying conditions of the different schools.

A list of questions requiring short answers is included in the appendices. This is intended for use by the teachers in order that they may test, periodically, the efficiency of the work. The appendices also include advice regarding practical work, apparatus, etc.

Finally the particular attention of the teacher is drawn to Appendix B.

It will be understood that, whilst one of us (H. W.) has been responsible for the physical sciences, and the others (M. A. G. and H. M. F.) for the biological sciences, the work as a whole has received uniform treatment.

The reader will notice that there is not a summary to Section III. Such a large field has been covered in this section that it has been difficult to prepare a summary for the space allotted. If the pupil works carefully through the questions and experiments at the end of the section, it will be found that all the main, outstanding features of the second-year scheme of work in Biology will have been thoroughly dealt with.

H. W.
M. A. G.

DUDLEY
1935

SECTION I. HEAT

Chapter 1

Where does all the heat come from?

In very early times, when savage tribes of people used to roam over our country, the most certain and regular supply of heat came directly from the sun itself Many of these savage people worshipped the sun as a god. They were afraid that if they did not do so, it would cease to provide them with light, warmth, and general comforts

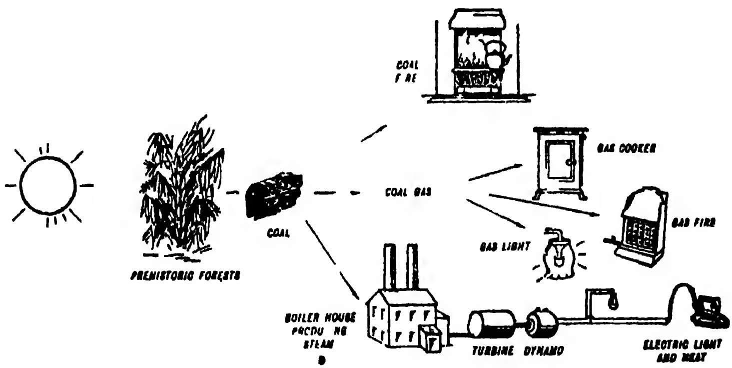


Fig 1 A diagram showing how all the heat comes from the sun

Although we do not worship the sun as a god to-day we have every reason to be thankful for it, because it supplies us, either directly or indirectly, with every bit of light and warmth that we use

Most of our heat and light comes from coal, or from gas made from coal, or from electricity. The electricity itself is made by machines called "dynamos". These machines are driven generally by steam-operated turbines. These, in common with all steam engines, derive their driving power from the heating value of coal

It has been proved almost beyond doubt, that coal is the remains of old trees that lived hundreds of thousands of years ago and during all this time have been buried in the earth. Heat and the pressure of the earth on top have caused the trees to turn into coal. You know that trees are not able to grow and develop without light, and as this is supplied by the sun, you can see that all the heat and light that we obtain from coal, comes indirectly from the sun.

Different means of obtaining heat

Heat by friction. Friction is the rubbing of two things together. If you rub your hands vigorously one against the other

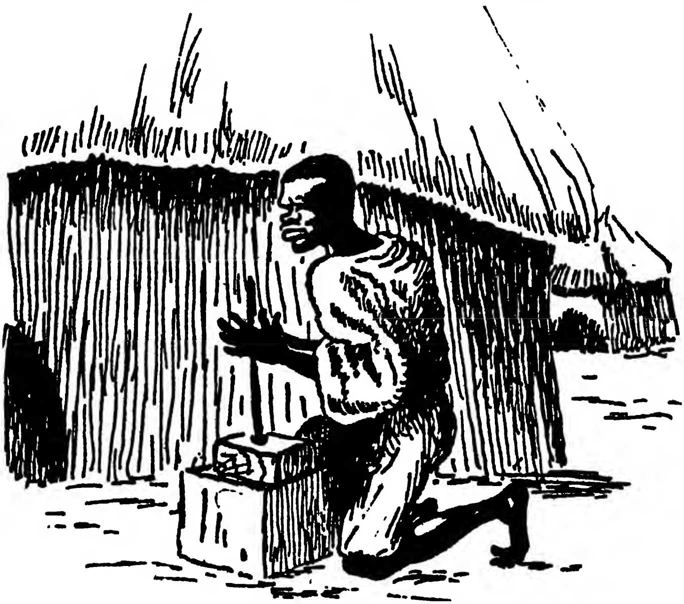


Fig. 2. A native making fire.

you will notice how warm they soon become. Horses sometimes make sparks by hitting their shoes against stones, and boys can

make sparks by kicking their heels sharply against the edge of the pavement.

It is believed that the earliest man-made fires were produced by means of friction, involving the use of wood. Even to-day natives in remote corners of the world, produce fire by rubbing two pieces of wood together, one piece being soft and the other hard. A stick of hard wood is rotated as a drill in a hole or depression in the soft wood (see Fig. 3). The dust that is produced from the soft wood eventually will smoulder from the heat of the friction.

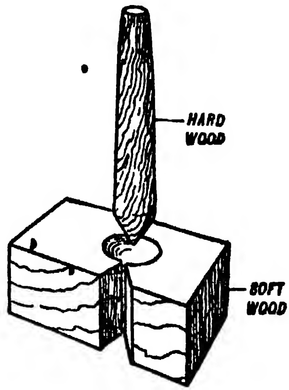


Fig. 3.

Sometimes fire was produced by rubbing a hard wood stick along a groove in the soft wood.

The tinder box. Prior to the introduction of matches, fires were started with the aid of the tinder box. This was an outfit consisting of a sharp flint-stone and a piece of steel, together with material called ***tinder***, which is very similar to charred cloth. Sparks were produced by rubbing the steel sharply against the flint and were allowed to fall on to the tinder. This latter then began to smoulder and would burst into flame when blown.

At the end of this section you will find instructions telling you how to make your own tinder box.

Matches. The earliest matches consisted of short sticks of wood topped with sulphur. They were held against the glowing tinder of the tinder box until they fired.

It was not until the seventeenth century, during Charles II's reign, that phosphorus was discovered. In spite of this, the first real phosphorus match was not invented until shortly after Queen Victoria's accession to the throne. These matches were very troublesome, as the amount of friction required to light

them often rubbed off their heads. Furthermore, they very often took fire if kept in a warm place, or if shaken about. It was not long, however, before red phosphorus was discovered. This substance was not a waxy substance like the ordinary phos-

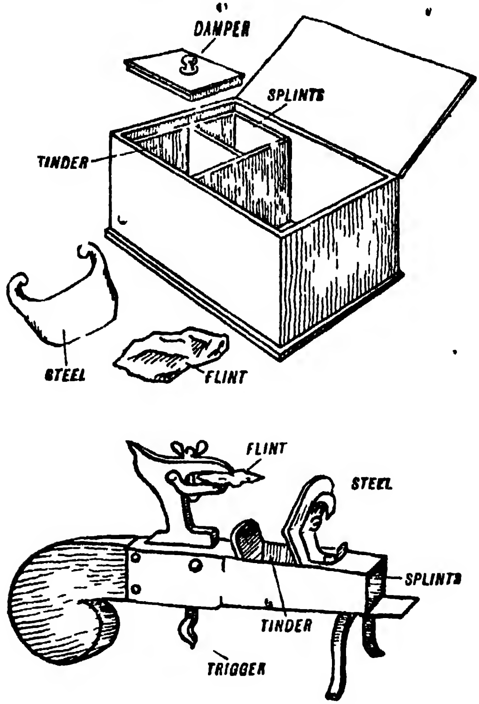


Fig 4 *a*, *b*. Tinder boxes.

phorus, but a brownish-red powder which did not catch fire so readily. The "safety" match of to-day contains very little phosphorus. The heads are made from potassium chlorate, a substance rich in oxygen, and antimony sulphide, a substance that readily catches fire. A mixture of red phosphorus, glass dust and glue is placed on the side of the box. When the match head

is rubbed on the specially prepared side of the box, the red phosphorus and glass dust will give tiny sparks. The temperature of these sparks is sufficiently high to fire the match head.

Other experiments in which heat is set free

The formation of oxides. When substances burn in air they join with the oxygen of the atmosphere, liberate (i.e. set free) a great deal of heat and form oxides.

Sometimes, however, substances will join with oxygen very slowly to form oxides. Consider the case of iron changing to rust. The iron joins with the oxygen of the air to form iron oxide. All the time this process is going on heat is evolved or given off but as the process is so slow the heat leaks away before it becomes noticeable.

Preparing dilute sulphuric acid. Concentrated acids are usually diluted by the addition of water.

Concentrated sulphuric acid is a powerful DEHYDRATER and is used for drying gases. Owing to its great affinity (i.e. its great liking) for water, therefore, care must be exercised in preparing dilute sulphuric acid. Water must never be added to the concentrated acid. The acid must always be poured steadily into the required amount of water and stirred well. Even with this precaution so much heat is evolved that the liquid almost boils.

Ask your teacher to pour about 40 c.c. of water into a small beaker and then to add, slowly and carefully, a similar quantity of concentrated sulphuric acid, the resulting mixture should be stirred well.

By feeling the outside of the beaker containing the mixture notice the amount of heat which has been liberated by mixing two liquids at normal room temperature.

The diluted acid can be bottled and set aside for future use.

The burning glass. The burning glass is, perhaps, more widely known as a "magnifying glass". It possesses the power of bending any light that passes through it, inwards, just as water appears to bend a stick when half the stick is held in water.

*If the glass is held in the rays of the sun it will bend them in*wards so that all the light and heat falling on it will be concentrated in one spot known as the focus (see Fig. 5). If a piece of paper is held behind the lens at the focus (the focus will be where you get the brightest spot of light on the paper) the concentration of heat will be sufficient to cause the paper to smoulder and eventually burst into flame.

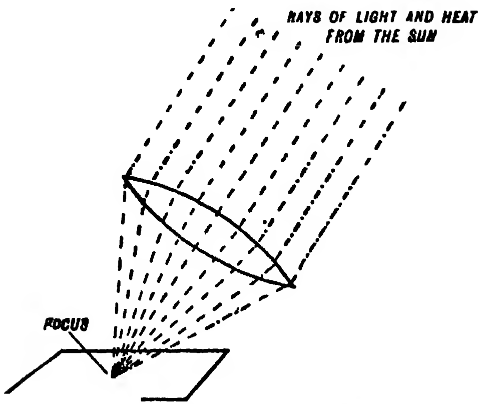


Fig. 5. How the burning glass works.

Coal and coal gas

Burning coal in the fireplaces at home and in works is a wasteful and often an unsatisfactory business Valuable products from the coal escape up the chimney or are burnt and deposited, as soot, on the chimney walls. In industrial areas the smoke, from the chimneys of the homes and factories, pollutes the atmosphere causing fogs in winter. It also hinders the growth of green plants. The smoke also deposits itself as dirt on buildings. Fortunately for us more and more factories are relying less on the power obtained through the direct burning of coal.

When coal is heated it gives off a mixture of gases known as coal gas and together with air this coal gas will burn and produce

a great amount of heat. Now if coal is baked without air being able to get to it the coal gas that is given off can be taken along pipes to the places where heat is required, and what remains of the coal can be utilised for other purposes.

William Murdoch, a Scottish steam engineer, was the first person to make coal gas. He did so in Cornwall, where he was working towards the end of the eighteenth century.

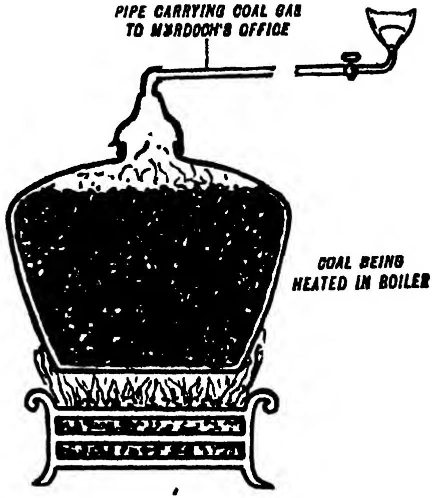


Fig. 6 A diagram showing how Murdoch first made coal gas to light his office.

Murdoch produced this gas by putting coal into a kind of boiler (see Fig. 6), which he heated. The gas that came off passed along a pipe to Murdoch's office. Here he lit it, and folks from miles around came to see the light that "burnt without a wick".

The present-day manufacture of coal gas will be readily understood when you have carefully studied Fig. 7. If there is a coal-gas works in your district try and persuade your teacher to arrange for your class to visit it.

Explanation of Fig. 7. The gas given off from the coal is cooled in a set of pipes called the ***condensers***, and tar together with steam and ammonia are condensed from the gas. In the ***scrubber*** the gas is washed by water that is continuously trickling over coke and brushwood. This washing removes ammonia. The ***purifier*** contains trays of lime and oxides of iron. These remove sulphur and carbon compounds from the gas. The purified gas then passes on to the ***gas holder***. Although various gas works have slightly different methods of producing coal gas, Fig. 7 gives a good idea of how the average one produces its gas.

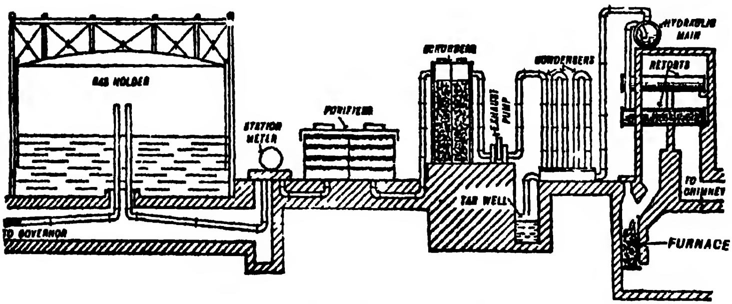


Fig. 7. A sectional diagram of a coal-gas works

The by-products. Although there is coal gas in the gas holder several other important substances that came off from the coal that was heated are obtained in other parts of the work.

These substances are called ***by-products*** and the chief of these are coke, tar, and ammonia. Of these three tar is by far the most important. Part of it is used in the crude state for roads, etc., whilst some is further treated, when aniline for dyes, benzol, and other valuable substances are obtained.

When you burn coal in the fireplace all these valuable by-products go up the chimney, either making soot, or polluting the atmosphere.

Gas burners.

(*a*) ***The Bunsen burner.*** The earliest gas burner was invented by a German Professor of Chemistry, named Bunsen. A diagram of the Bunsen burner is shown in Fig. 8. The gas enters the burner through a fine jet in the base and its uprush sucks in air through the air hole. This mixture of air and coal gas can be lighted at the top of the Bunsen tube, when it will burn

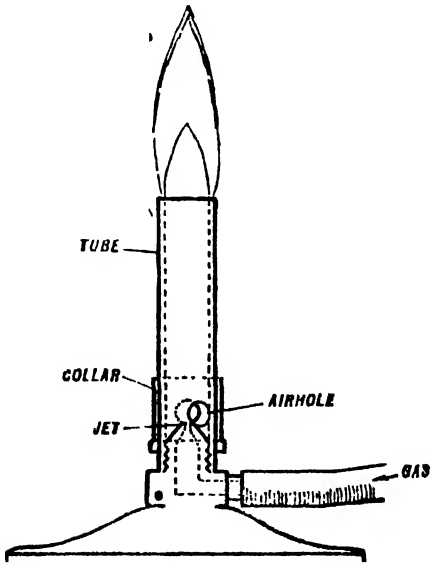


Fig. 8. The parts of a Bunsen burner.

with an extremely hot non-luminous flame. To give a very hot, satisfactory, and economical or cheap flame the mixture should consist of about three parts of air to one part of coal gas.

The size of the hole admitting air to the Bunsen tube can be controlled by a collar which can be turned to cover the hole. When the air hole is closed up the flame becomes bright or luminous, and sooty. This luminous flame does not possess as much heat as the non-luminous one.

Inside each of the Bunsen flames there is a blue cone or region. These give you the impression that there are two flames—one burning inside the other. The blue region, however, is one of unburnt gases—the blue shows where the gases are commencing to burn.

If a glass tube is held in the blue region of the Bunsen flame some of the unburnt gas will pass up it. This gas can be ignited, or set fire to, at the top as shown in Fig. 9.

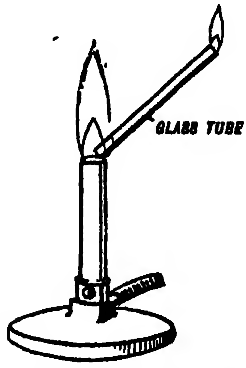


Fig. 9. The inner blue cone of a Bunsen burner is a region of unburnt gas.

When lighting the Bunsen burner care must be taken first to turn the gas on full, and then to bring a light to within about one inch of the top of the tube. If the light is held at the top of the tube and then the gas is slowly turned on the flame will travel down the tube and light the gas at the fine jet. This is called ***backfiring***, ***striking back***, or ***lighting back***, and must be avoided. Backfiring also takes place if too much air is drawn into the tube through the air hole. In this case the air inlet must be made smaller. Backfiring also applies to other gas burners. The occasional backfiring of a Bunsen burner can be cured very

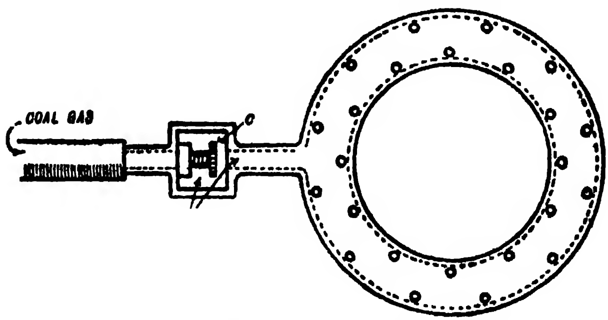


Fig. 10. A gas ring.

rapidly by hitting the rubber tubing sharply with the side of the hand.

(*b*) ***The gas ring.*** As the gas passes the screw head *C* (see Fig. 10) it draws air with it into the mixing tube. Each small flame coming from the holes in the ring is similar to the Bunsen burner flame. The inflow of air can be regulated by screwing *C* in or out.

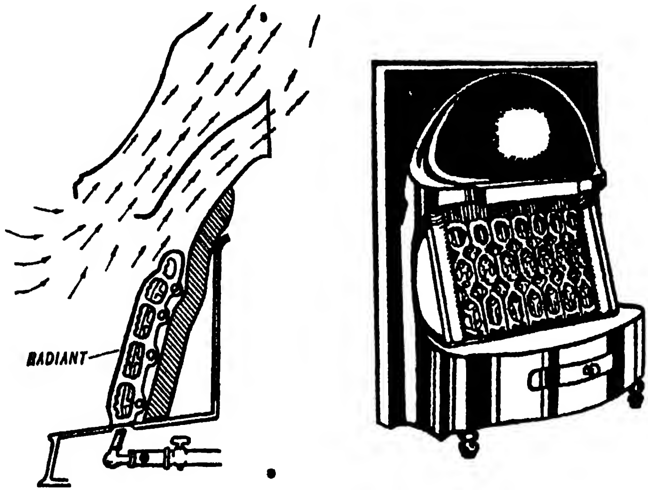


Fig. 11 *a*, *b* Gas fires.

(*c*) ***The gas fire.*** The front of the gas fire is made up of a kind of ornamental fire-clay tube. Underneath each of these skeleton-like tubes, which are called ***radiants***, a non-luminous coal-gas flame burns. The heat of the flame causes the radiant to become red hot and so give off heat.

The electric fire

Gas fires have a serious rival in the electric fire. Here the red heat is obtained from a special type of wire which becomes red

hot when electricity is allowed to pass through it. In Book III you will learn why the wire becomes red hot.

Fig. 12. An electric fire.

Why care must be exercised in the use of coal gas

*1. **Coal gas is poisonous.*** Many people have died from coal-gas poisoning. Even a slight escape of gas in the house is sufficient to make people ill, so that when you have finished using the gas always see that you have turned off the tap properly.

*2. **A mixture of coal gas with air is highly explosive.*** Take a cocoa tin with a hole in the centre of the base about ½ an inch in diameter and one in the centre of the lid about ⅛ of an inch in diameter, and fill it with coal gas. You can do this by placing a finger over the hole in the lid and holding the bottom hole over the Bunsen burner for 5 or 6 seconds. N.B. The collar of the Bunsen must be closed.

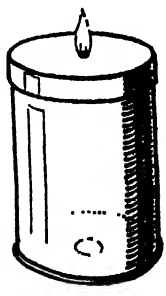


Fig. 13.

Now remove your finger and light the gas coming through the hole in the lid. As the gas burns away at the lid air enters to take its place through the bottom hole of the tin. When the flame, gas, and air meet, a loud explosion will take place which will blow the lid right off. If the tin is held in the hand it must be held at arm's length.

When entering a house in which gas has been escaping first turn off all gas taps and then open all the windows and doors.

Also,

Coal gas is lighter than air. Soap bubbles filled with coal gas can be blown by connecting a piece of Bunsen burner tubing to the gas pipes, turning on the gas gently and dipping the open end of the tubing into a soap solution. These bubbles give off delightful colours as they increase in size and when they have freed themselves they rise immediately to the ceiling. This is because the coal gas is very much lighter than air and can easily carry the soap film with it. You will notice that soap bubbles blown with your own breath sink to the ground. If one of the larger coal gas filled soap bubbles is lit on its journey to the ceiling an excellent impression of the biblical "ball of fire" will be obtained.

Chapter 2

HOW HEAT TRAVELS

(*a*) ***Conduction***

You know that when the end of the poker is left in the fire it becomes red hot, and if left there for a while the handle, too, becomes very hot—too hot to hold comfortably. Heat has travelled from the fire through the poker to the handle by passing

from one piece of iron on to the next. This method of heat passing along a substance is called ***conduction.***

When you open a door or gate the iron handle or latch feels cold—colder than the wood. This may seem very peculiar to you as the whole of the gate is under the same conditions of heat and cold. Actually, although the one feels colder both the latch and the wood are as cold as each other. The reason for this is that the iron is a far better ***conductor of heat*** than the wood and conducts the heat so rapidly away from your hand that it is left feeling cold.

Dip your fingers first in water and then in mercury. You will soon discover that the latter is a much better conductor of heat than water, because it feels so very much colder.

All metals are good conductors of heat, although their conductivities, i.e. their power of conducting heat, varies. Kettles and boilers are made of metal because the metal enables the heat to pass through to the water quickly. In addition the metal is better able to withstand the effects of heat than the majority of substances. Poor or non-conductors of heat include all clothing material, wool, silk, and leather, paper, wood, glass, crockery, bone, flesh, skins of animals, all liquids with the exception of mercury, and, last but not least, air.

The explanation of the conduction of heat

You will remember from Book I (Section I, Chapter 2) that all substances are made up of tiny particles called ***molecules.*** These molecules are in constant motion—jumping about and bumping into each other. Now when substances are heated the molecules jump about more rapidly, and so more frequently collide or bump into each other. It is by this jumping and bumping about of the molecules that the heat is handed from one portion of the substance to the next. It follows from this, that substances whose molecules are far apart (see Book I, p. 30), such as liquids and gases, are poor conductors of heat. The majority of the best non-conductors of heat are loose in texture

and retain a great deal of air—one of the poorest conductors of heat.

A paper saucepan

If a paper box is made and filled with water it can be placed on a burner (as shown in Fig. 14) and heated until the water boils. The paper will not burn because the water inside carries the heat away before it is sufficient to set fire to the paper

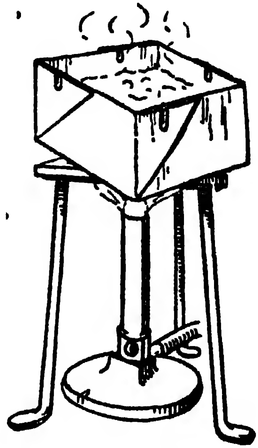


Fig 14. Boiling water in a paper vessel.

Paper clothes

Although paper kettles and saucepans will not burn if used properly paper is not suitable for making such utensils. This is partly because paper is such a poor conductor of heat that the heat cannot pass through to the water quickly enough.

During the Great War clothes were often made from paper, particularly in Germany where wool and cotton were very scarce. Paper is such a bad conductor of heat that it prevents heat escaping from the body. The only drawback with paper clothes is that they do not wear well.

In wintry weather poor people often lay sheets of thick brown paper between the blankets on the bed. This brown paper acts as an additional blanket.

Tramps often put sheets of brown paper across their backs and chests to keep out the cold winds.

Blankets keep warm things warm and cold things cold

During wintry weather more blankets are included in your bed-clothes because they are such bad conductors that the heat is prevented from escaping from your bodies. In this way blankets keep you warm.

In the summer, however, the ice-man carts his ice around the streets wrapped in blankets to keep it cold. In this case the poor conductivity of the blanket prevents the outside heat from getting through and melting the ice.

Thatched roofs

Many old houses and cottages in the country have thatched roofs. These roofs act in a similar way to the blanket above, by

Fig. 15. A thatched cottage

keeping the houses warm in winter and cool in summer. The poor heat conductivity of thatched roofs is due, largely, to the air retained in its loose texture.

The earth is a bad conductor of heat

When our world first began, the earth is supposed to have been a molten mass. Many people believe that originally the earth was part of the sun that became detached and so shot off

into space. Although during the ages the earth's crust has become sufficiently cool for us to walk or swim about on its surface it is still very hot in the interior. Evidence of this can be obtained from volcanic eruptions that take place from time to time in various places on the earth's surface If earth were not a bad

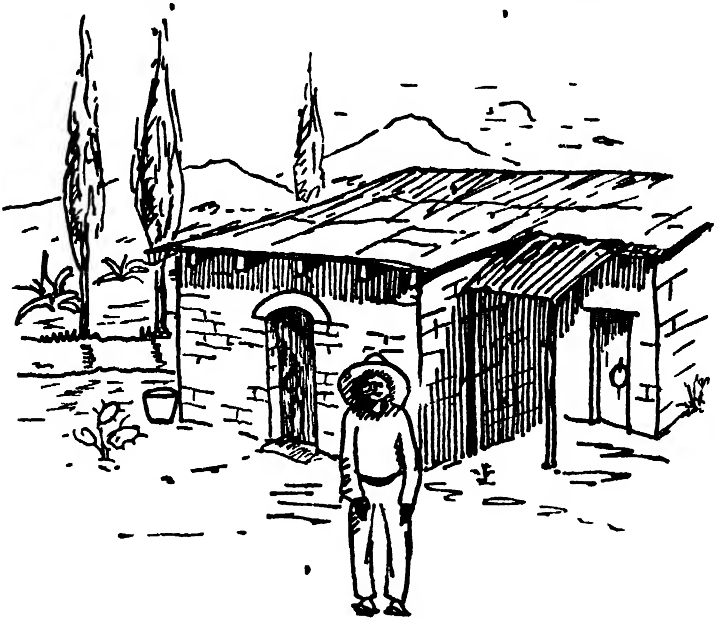


Fig 16 A Mexican clay or adobe house

conductor of heat that heat from the interior would quickly pass through to the surface and kill all living things

In many of the hotter parts of the world houses are made from mud. The walls are thick and not only provide shade but also keep the interior of the mud house cool.

A cooking box

A cooking box is a box made from a non-conducting material, such as wood or cardboard, which is thickly lined with another

non-conducting material, e.g. hay (see Fig. 17). The porridge, or stew, or whatever has to be cooked, is brought to the cooking point and then placed inside the box. As little or no heat can escape the food goes on cooking.

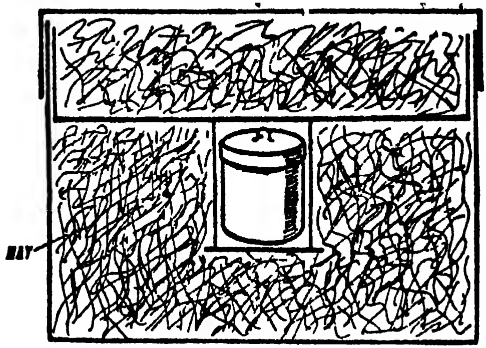


Fig. 17. A cooking or hay box.

Metal tea-pots and coffee-pots

The handles of these pots are often made of wood. If the handles happen to be made of metal you will see two buttons of insulating or non-conducting material such as bone, china or ivory between the handles and the body of the pot (see Fig. 18).

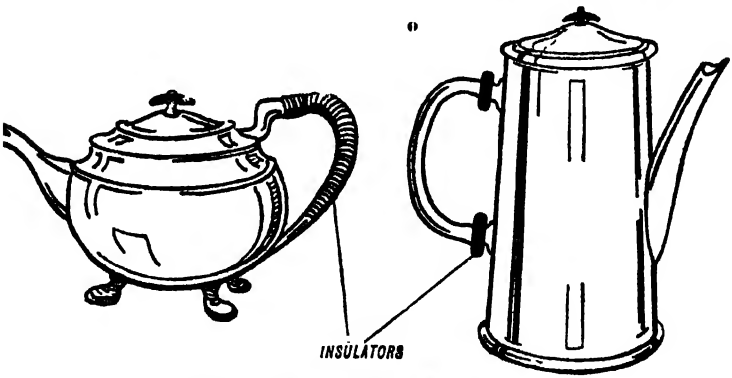


Fig. 18. Insulated handles of tea-pots.

These insulators or non-conductors prevent the heat of the pot from reaching the handle.

Some good conductors and their uses

Iron wire gauze and the Davy (miners') safety lamp. Hold a piece of iron wire gauze 1 or 2 inches above the tube of a Bunsen burner. Turn on the gas and light it above the gauze. The gas will go on burning above the gauze but not below it (see Fig. 19*a*). The reason for this is that the iron wires of the gauze

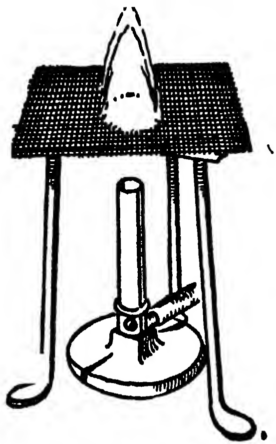


Fig. 19*a*.

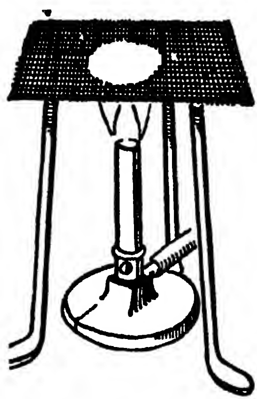


Fig. 19*b*.

conduct the heat so rapidly away that the temperature underneath the gauze is too low to set the gas alight. In the same way, if you had lighted the gas beneath the gauze instead of above, the flame would only burn beneath although unburnt gas would pass through. This can be proved by lighting the gas above the gauze. Now you have gas burning above and below the gauze.

Sir Humphry Davy made use of this knowledge by inventing a safety lamp for miners. This lamp consists of a burner surrounded by wire gauze (see Fig. 20). When the lamp is lighted the gauze conducts the heat of the flame away so that there is

not sufficient to explode any explosive gases that exist outside the lamp.

Prior to Sir Humphry Davy's invention there had been very frequent disasters in coal mines due to explosions caused by

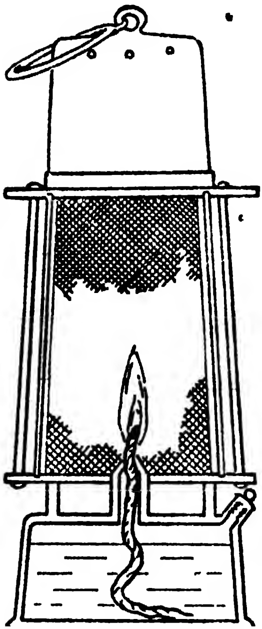


Fig. 20. A Davy safety lamp.

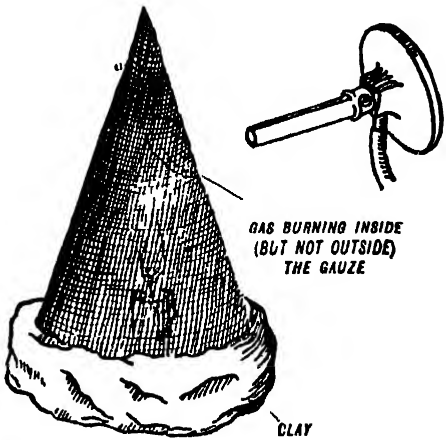


Fig. 21 A model Davy safety lamp.

"naked" lights that the men often used We still have explosions in coal mines, but, fortunately, they are very rare.

You can make a simple safety lamp for yourself by sticking a lighted candle into a lump of clay and pushing a cone of iron wire gauze over it.

Coal gas, as you know, is explosive. Direct a stream of it from the Bunsen burner towards your safety lamp as shown in Fig. 21. Only that gas which passes into the lamp will burn.

The cooling fins of the motor-cycle engine. The metal on the outside of air-cooled engines is drawn out, as it were, into thin layers which are separated from each other by air. These layers are called ***cooling fins***, and act in a manner similar to that of the strands of metal in the wire gauze. The heat of the

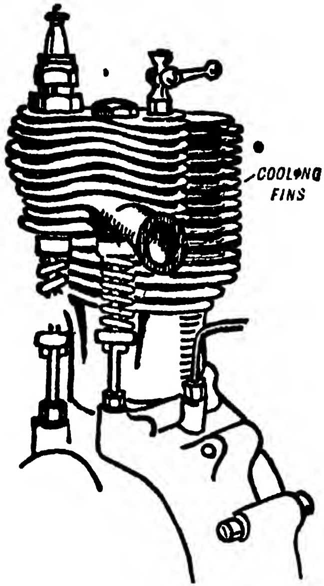


Fig. 22. A motor-cycle engine showing the cooling fins.

engine is passed out along these fins, which are so thin and have such a large surface area that they quickly get rid of the heat to the air.

(*b*) *Convection*

On p. 14 you learnt that as the molecules of liquids and gases are much farther apart than those in solids they are unable to hand heat from one to another very well.

Consequently liquids and gases are found to be poor conductors of heat. Both liquids and gases, however, can be fairly rapidly heated. The particles that are closest to the source of heat move away when they have become hot, generally in the upward direction, carrying their heat with them. Fresh colder particles take the place of the heated ones. These in turn become hot and move away thus making room for other colder ones. In this way when liquids or gases are heated we get streams or currents of the substance moving about. These currents are called ***convection currents.***

To show how water becomes hot

Drop a crystal or two of potassium permanganate into a beaker full of still water. After waiting for about 30 seconds

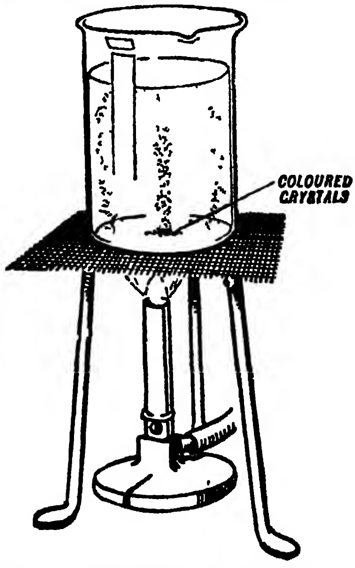


Fig. 23. Convection currents in water.

place a lighted Bunsen burner underneath the beaker. The water just above the flame begins to rise and its place is taken by colder

water from the sides. The current* of warm water can be seen rising by the fact that it carries the colouring matter with it. The water goes on circulating, i e. moving round in currents, so that it eventually gets warmed up to boiling point.

To show that water is a bad conductor of heat

By means of a folded paper holder hold a test tube two-thirds filled with water in the Bunsen burner flame so that the water

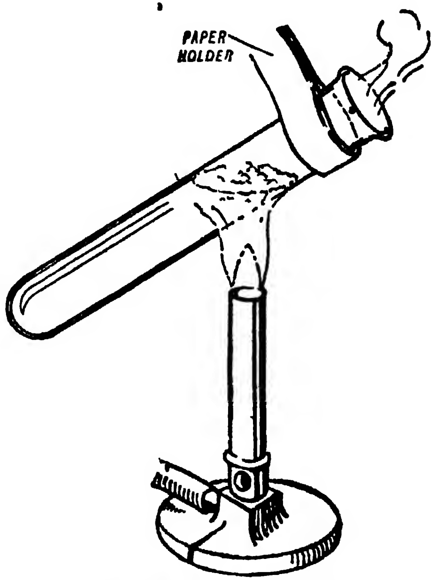


Fig. 24. Water is a very poor conductor of heat.

can boil at the top as shown in Fig. 24. Take care to keep the flame below the water line, otherwise the glass will crack.

* A sheet of white paper held behind the beaker will show up the path of the currents more clearly.

This experiment will act quite well if sawdust is used instead of potassium permanganate. Here, however, you should notice the path taken by *one* of the pieces of sawdust.

Although the water at the top soon boils you can safely touch the bottom of the tube, which you will find quite cold.

To show what happens to air when it is heated

Take a piece of circular cardboard about 6 inches in diameter and, with a pair of scissors, cut it in spiral form as shown by the heavy line in Fig. 25 *a*. Make a wide pinhole at X and suspend

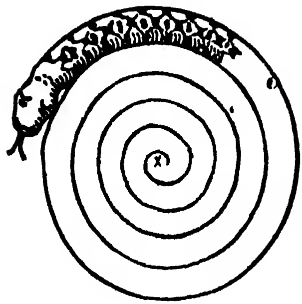


Fig 25 *a*

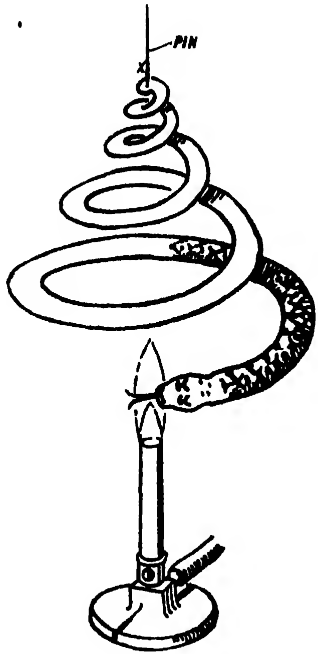


Fig 25 *b*.

the spiral by means of a pin 2 or 3 inches above a candle flame Immediately the spiral will begin to revolve. If the non-luminous Bunsen burner flame is used instead of the candle flame the spiral will spin round very rapidly The reason for this is that the air particles around the flame become warmed up, and, like the heated water particles, they rise carrying their heat with them. This rising current of air pushes against the spiral and causes it to revolve

A very realistic effect can be obtained by painting the spiral to resemble a snake.

One of Nature's wonders

All liquids (with one exception) and gases, when heated, become lighter and rise in the form of currents. The reason for this is that the heat causes them to expand, i.e. to swell out or become larger. The exception is water (see Book I, pp. 29 and 30), which expands when it is cooled from 4° C. to freezing point, i e. 0° C. Under these circumstances the cold water rises, and so at freezing point we have ice forming on the top instead of on the bottom of the water.

This freak is one of Nature's methods of safeguarding itself. If ponds were to freeze from the bottom upwards all the animals that lived in them would be killed. In addition ice is a poor conductor of heat and when a stretch of water is frozen over the ice prevents the water beneath it from becoming colder.

Wind and breezes

The formation of a wind, which is nothing more than moving air, is due entirely to the rising of hot air. During the daytime

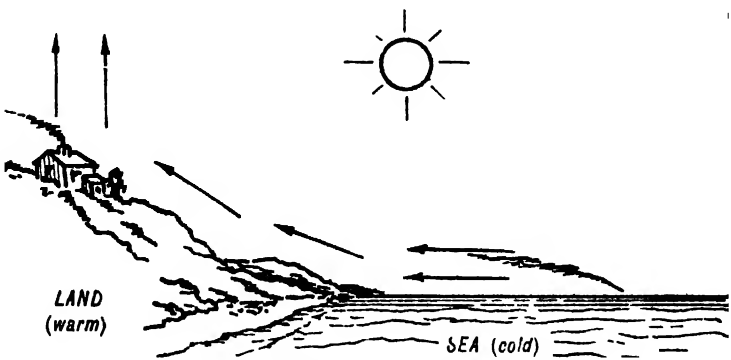


Fig. 26 The formation of a sea breeze

at the seaside the land becomes hot more quickly than the sea. As a result the air over the land becomes warm and rises while colder air blows in from the sea to take its place; this movement of air is known as a ***sea breeze*** (see Fig. 26).

At night the land becomes cooler much more quickly than the sea. The sea being warmer than the land causes the

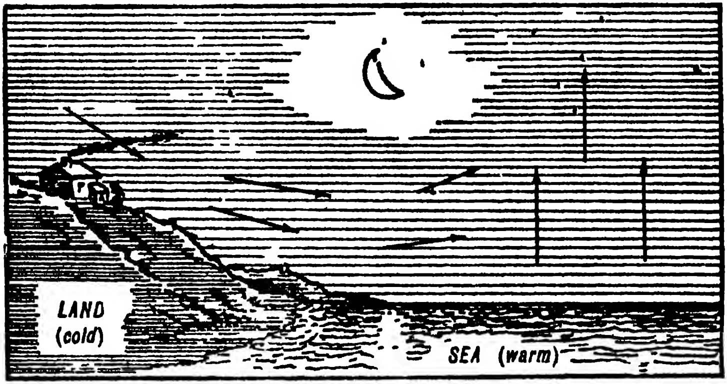


Fig 27. The formation of a land breeze

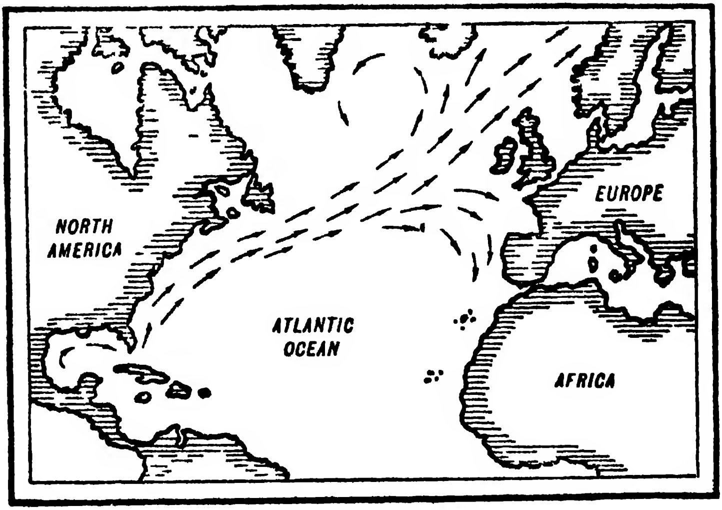


Fig 28 The Gulf Stream.

air above it to rise. This air is replaced by cooler air coming from the land. It is in this way that a ***land breeze*** is formed.

Many years ago, when fishing vessels used to depend upon sails for their motion, the ships would put to sea at nightfall.

All winds, however strong they may be, are caused, in the first instance, by different places on the earth's surface being warmer or colder than those near by.

Ocean currents

Currents in the ocean are formed in a manner similar to that which causes winds. The waters of the ocean's surface at the equator are quickly heated by the very powerful rays of the sun. They move away from the equator and are then replaced by cooler water from beneath. The direction of these ocean currents is influenced by winds and the spin of the earth. The Gulf Stream, a mighty stream of warm water, comes from the Gulf of Mexico straight across the Atlantic and passes close to the British Isles. The mildness of our winter is due to the influence of this Gulf Stream.

How our knowledge of convection currents has been put to practical use

Hot-water systems. In our public buildings, schools, and sometimes houses, pipes, in which we cause hot water to circulate, run round the rooms. A boiler is kept in the basement of the building, from the top of which a pipe runs up-

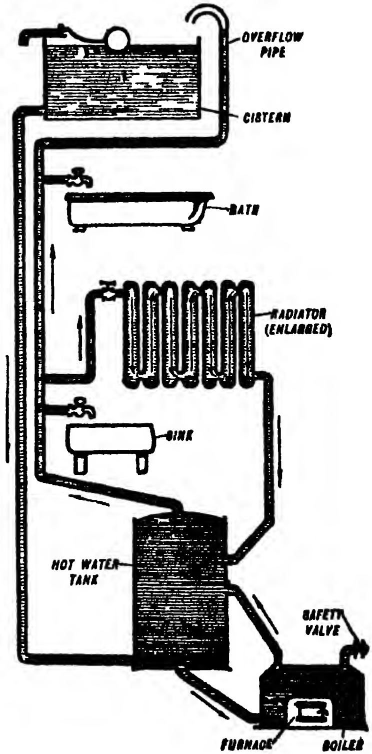


Fig. 29. A diagram of a hot-water system.

wards round the building. Hot water from the boiler runs up this pipe and branch pipes carry the hot water round the rooms to pipes, bath and sink taps. A return pipe carries the cooled water back to the bottom of the boiler, where it is reheated and sent on its travels once again. In order to replace the hot water

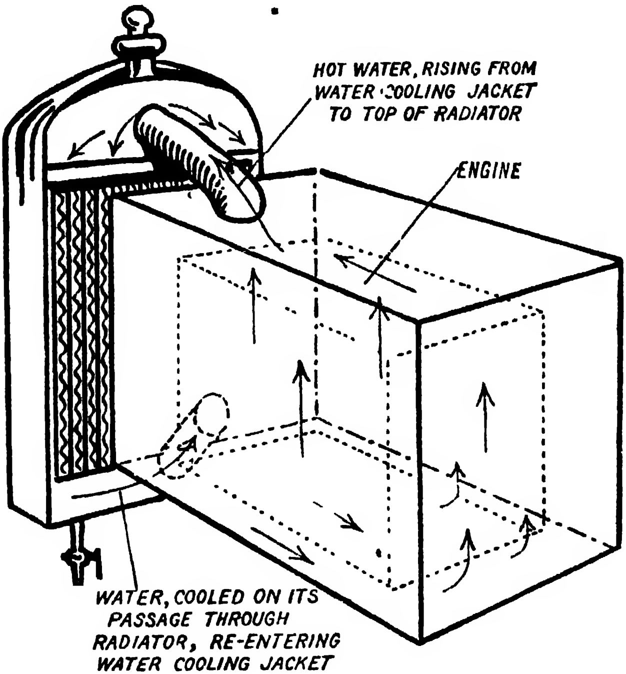


Fig. 30.

used from the bath or sink taps, fresh cold water from the ball-valve cistern enters at the bottom of the boiler.

Water-cooled engines. It is not very practicable to cool large motor-car engines by air as we do in the case of motor-cycle engines. The majority of motor-car engines are surrounded by a kind of jacket in which water flows. This water jacket has a

pipe leading from it to the top of the radiator, which is in front of the car. Another pipe leads from the bottom of the radiator to the bottom of the water jacket. When the engine is running, the water in the surrounding water jacket becomes heated and rises in the pipe to the top of the radiator. The hot water then slips down pipes in the radiator, where it is cooled by air rushing through the "honey-comb". The cooled water enters the bottom of the water jacket. The cooling of the water when it is passing through the radiator is assisted by a fan. In larger engines the circulation, i.e. the continual passing round of the water, is assisted by a pump.

Ventilation. Ventilation is the constant renewal of the air in a room so that it is kept fresh and pure.

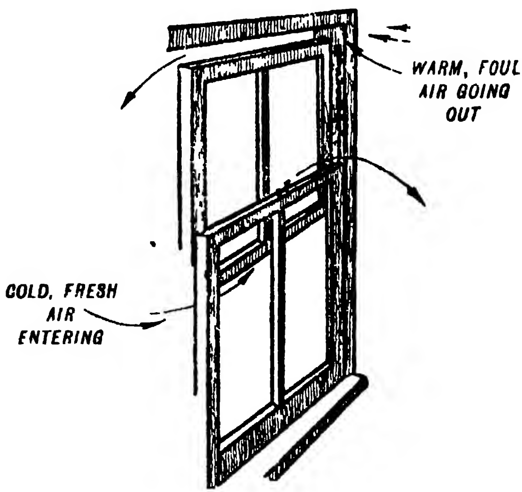


Fig 31 The method of ventilating a room by means of a sash window

In rooms where there is a fireplace the cold air will move towards the fireplace, become warm, and rise, mostly up the

chimney. Fresh air will enter the room through the door or open window or special ventilators. It is very necessary that the fresh air entering a room should not form a draught. In cold weather if you have no special ventilators to the rooms of your house it is best to let the fresh air in and the foul air out by opening the top half of the window only (see Fig. 31). The warm foul air gets out at the top of the window and cold fresh air enters at

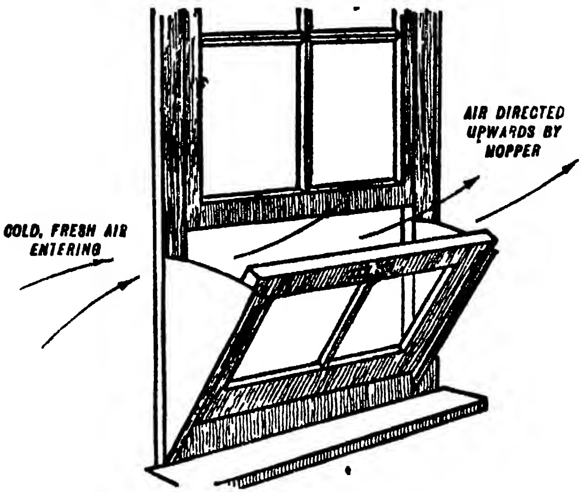


Fig. 32. A hopper window.

the middle of the window. This fresh air being colder, and therefore heavier than the air already in the room, sinks gradually, but in doing so becomes slightly warmed. There are several devices by which fresh air entering the room is directed upwards to avoid a draught. The hopper window (see Fig. 32), which is often found in schools, is one of these.

The ventilation of coal mines is a matter of great importance in order to prevent poisonous and explosive gases from accumu-

lating and lingering in the passage. Two shafts are sunk to each mine, a downcast shaft and an upcast. Years ago at the bottom of the upcast shaft a huge fire was kept burning. This fire created a powerful upward draught because of the hot air, above it, rising. Consequently fresh cold air was drawn through the downcast shaft and along the passages of the mine. Nowadays powerful electric fans are used to draw air through the mines.

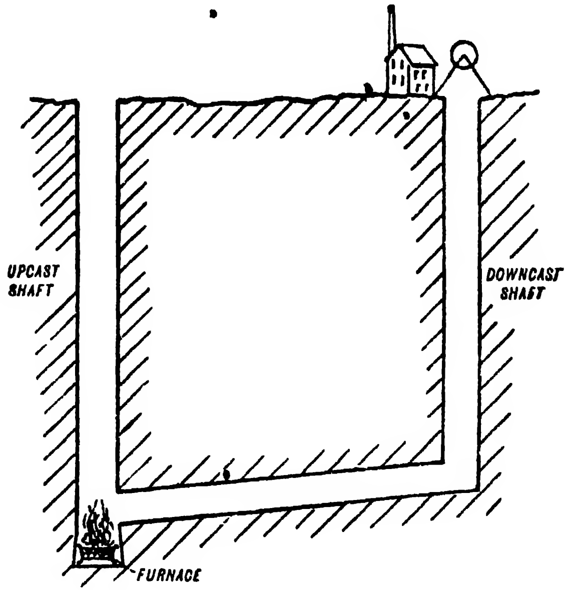


Fig. 33. The old-fashioned method of ventilating mines.

(c) *Radiation*

What it is

In the winter when you are cold you often warm your hands by holding them in front of the fire. Your hands soon become warm; the redder the fire the more quickly do they become warm. But your hands do not touch the fire. How, therefore,

do they become warm? By conduction? This is hardly likely, because there is only air between your hands and the fire, and air is a very bad conductor of heat. Is the heat of the fire brought to your hands by convection currents? The answer is again—no! The air which is heated by the fire rises, carrying its heat away from your hands, which are in front of the fire. The heat reaches your hands by what is known as ***radiation***. In this method the heat travels by means of rays just as light travels in rays from the sun.

The heat from the sun

It is by means of radiation that the heat of the sun reaches us.

The air that we breathe is held to the earth by the force of gravity: consequently for the larger part of the distance between

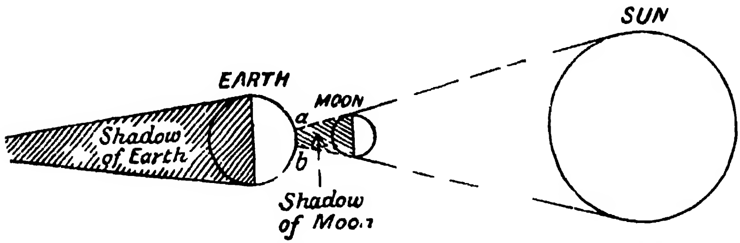


FIG. 34. Showing how an eclipse of the sun is formed. People living between *a* and *b* on the earth's surface will experience cold at the same time as the sun's light is cut off

the earth and the sun there is no material by which the sun's heat could be brought to us by conduction or convection.

Scientists have supposed that there is an invisible substance called "ether" (sometimes spelt "aether") by means of which rays of light, and heat, and even those of electricity called ***wireless waves***, can travel about in space in all directions. Light and wireless waves are known to travel at the enormous speed of 186,400 miles per second. Now when an eclipse of the sun takes place it is found that the light and heat are cut off at the

same time. Consequently rays of heat must also travel at 186,400 miles per second.

Light, heat, and wireless waves travel outwards from their sources in very tiny wavelets. An exaggerated impression of the wave motion can be obtained by dropping a pebble into a still pool.

Ripples or wavelets will move outwards from the spot where the pebble was dropped into the water. Fig. 35 shows a plan (very much out of proportion) of the way in which waves are

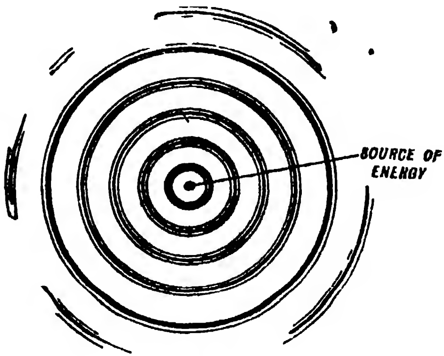


Fig. 35. A plan and at the same time a side elevation of the way in which waves are sent out from a source of energy

sent out from a source of energy. Light, heat, and electricity are forms of energy because they can be used up to do work. For example, heat will turn water into steam, which will, in turn, drive a steam engine.

Radiated heat scarcely warms transparent substances, such as thin glass, through which it passes. Opaque, that is non-transparent, substances on which the radiated heat falls, partly absorb or take in the heat, and partly reflect it, just as a mirror reflects light. As the full effect of the sun's heat is not felt until it has been reflected from the earth's surface, we find the air

very cold on the tops of high mountains. It was very necessary for balloonists of years ago to wrap themselves up in the manner of an Arctic explorer before making an ascent. Nowadays aeronauts use some form of enclosed cabin

White clothes

You have just read that opaque or non-transparent substances partly absorb and partly reflect any radiant heat that falls upon

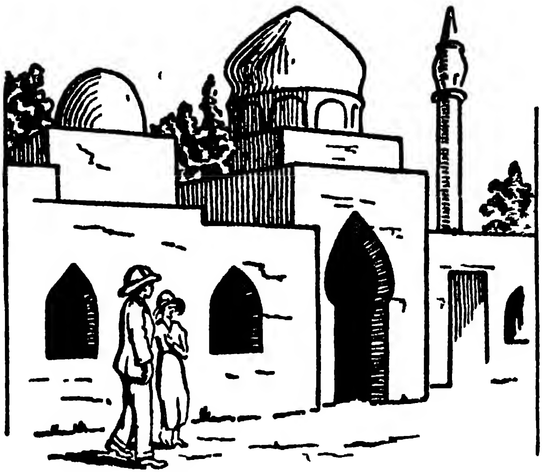


Fig. 36. White buildings and tropical clothing

them. Highly polished or white substances, however, reflect most of the heat falling on them, whilst dark roughened surfaces absorb most of it.

White people who live in tropical countries wear thin white clothes, because the white material "throws back" or reflects the heat of the sun. Even in this country, cricketers and tennis players wear white clothes when they are playing in the summer Many of the houses in hot countries are painted white so that they shall be cool within.

Very often, nowadays, the backs of firegrates are made of a long slab of firebrick tilted forward at the top end. This firebrick gets hot and radiates into the room heat which would otherwise have gone up the chimney

Polished tea-pots

All objects that are hotter than their surroundings radiate heat. Those objects with white or polished surfaces, however, radiate very little heat, whilst those with darkened surfaces lose their heat by radiation rapidly.

A polished metal tea-pot will retain the heat of the tea for a reasonably long time on account of its surface.

A radiation experiment with two cocoa tins

Take two cocoa tins of the same size and coat the surface of one with lamp-black varnish.* Now stand the two tins on

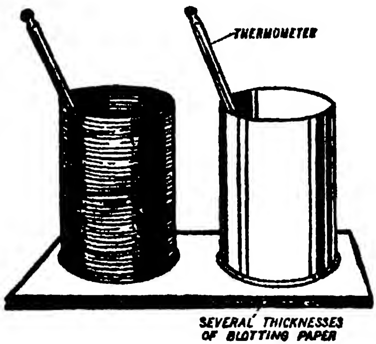


Fig 37.

several thicknesses of blotting paper and fill them with equal quantities of boiling water. Put a thermometer into each tin and after taking the temperature at the commencement take it again

* An excellent lamp-black varnish which will give a lasting surface can be obtained by grinding up the lamp-black with thin shellac varnish and turpentine.

every five minutes. Record your result in a table as shown in Fig. 38.

Time	Temp. of black tin	Temp. of polished tin
0 min		
5 ,,		
10 ,,		
15 ,,		
20 ,,		
25 ,,		
30 ,,		

Fig 38

The "thermos" or vacuum flask

You have all seen a vacuum flask, often called a "thermos" flask, and know that it will keep liquids, such as tea, coffee, and

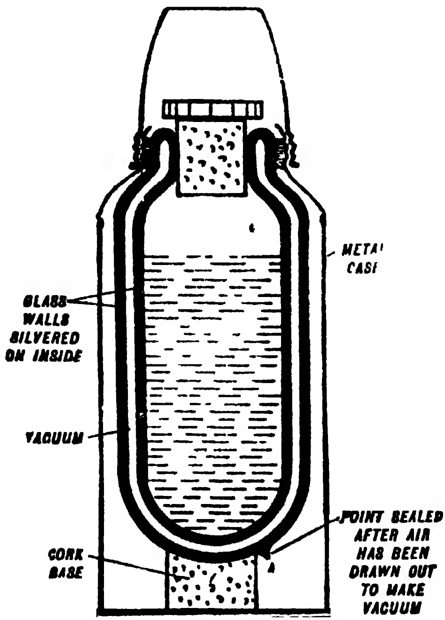


Fig. 39. A section showing how the vacuum flask is made.

soup, hot for twenty-four hours or more, and will keep iced liquids cold for a week. How does it do this? This question will be best answered by first taking the flask to pieces and examining it.

The inside vessel is a kind of double-walled thin glass bottle the inner walls of which have been silvered all over. The space between the walls is a vacuum, the air having been withdrawn through the projection *A* (see Fig. 39) in the process of manufacture. Both the stopper and the base for the bottle to rest on are made of cork.

Whether there is a hot or a cold liquid inside the flask the former cannot lose much heat or the latter gain much heat from outside, by

(*a*) radiation owing to the silvered surface,

(*b*) convection because of the absence of air,

(*c*) conduction, because the glass of the bottle and the cork of the base and stopper are both bad conductors of heat.

Chapter 3

THE EFFECTS OF HEAT ON SUBSTANCES

Expansion and contraction

When substances are heated they grow larger or ***expand***, and when they are cooled they become smaller or ***contract***. (Water between 0° C. and 4° C. is an exception to this rule. See p. 25.) This expansion or contraction is not very considerable except in the case of gases. Here it is most noticeable.

All substances become less dense and therefore lighter when they expand and heavier when they contract.

Why substances expand when heated, and contract when cooled

On p. 14 we read that the molecules of all substances are constantly moving about and bumping into each other. Now when

substances are heated the molecules begin to jump about more rapidly like the proverbial "cats on hot bricks". But if cats really were put on to hot bricks you can well imagine that they would jump higher and further as the bricks became hotter and hotter. This is so when a substance is heated—the molecules move about over a wider range and so the substance expands.

The expansion of gases

Hold the neck of a medicine bottle under water and warm its surface with a lighted match. Bubbles of air will be seen to

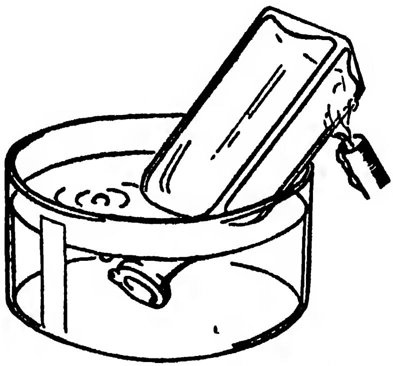


Fig. 40. The expansion of gases.

escape from the bottle because the heat of the flame has caused the air to expand and to grow too large to be contained by the bottle.

Another expansion of gases experiment

Pour water into a bottle until it is about one-quarter full, and then tightly cork it up with a stopper which has a long glass tube passing through it. If now you place your hands on the outside

of the bottle as shown in Fig. 41, the expansion of the air trapped in the bottle will be very noticeable by the water rushing up the narrow tube.

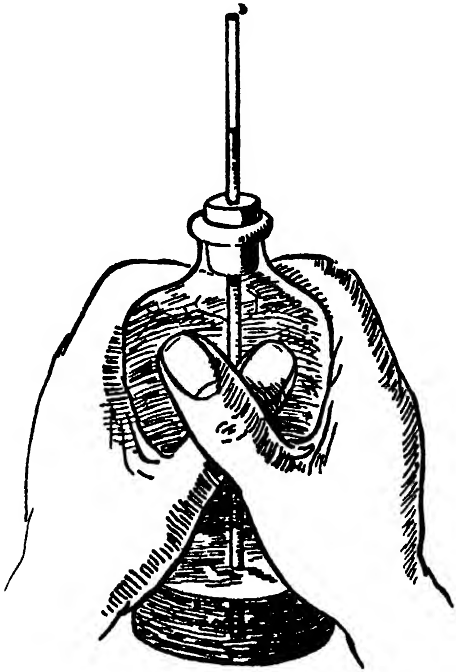


Fig. 41.

Early balloons

The fact that air expands enormously and so becomes very much lighter was used in the construction of early balloons, called fire balloons. Two brothers, Frenchmen named Montgolfier, were the first to put this into practice. Their best balloon was made of linen, 105 feet in circumference, and this they

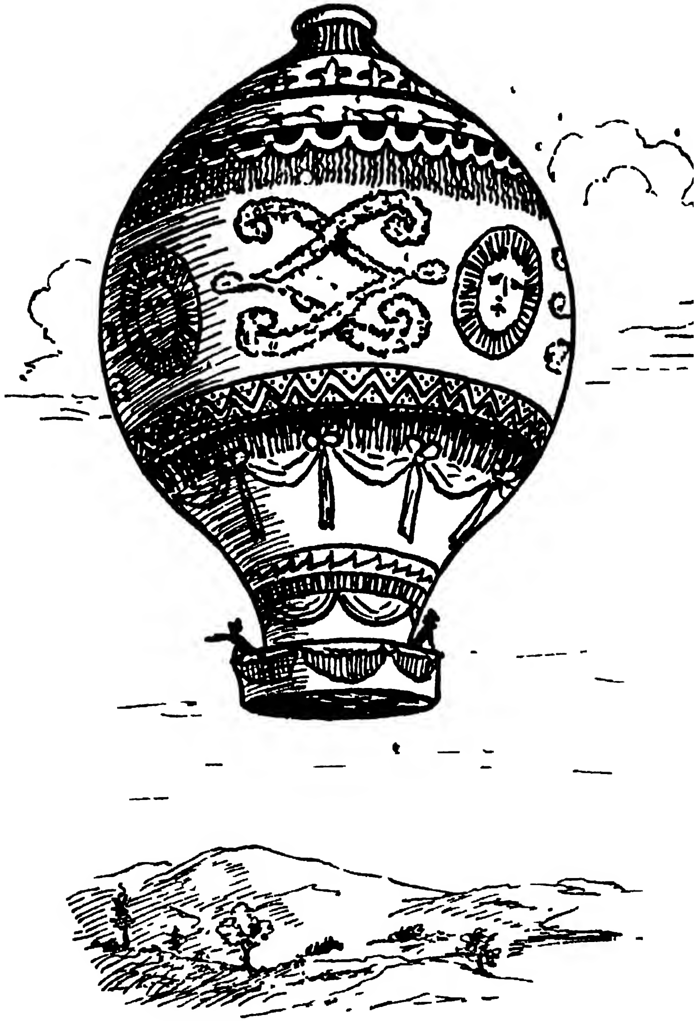


Fig. 42. A picture of the Montgolfier balloon ascending.

inflated or filled over a fire fed by chopped straw. Of course when the air inside the balloon cooled down the balloon gradually descended.

We still use small fire balloons at fêtes and firework displays; these are made from tissue paper. The mouths of these fire balloons are kept open by a wire ring, at the centre of which is a lump of cotton wool soaked in methylated spirits. When the cotton wool is lighted it provides hot, light air to make the balloon rise.

The expansion of liquids

Fit up the apparatus shown in Fig. 43. If the flask is filled to the brim before the cork and glass tube are inserted some of the coloured water will go up the tube as shown. Mark the level of the water in the tube. Warm the flask of water by putting your hands around it. At first you may notice that the water level in the tube is falling. This does not mean that the water is contracting. The glass is heated first and expands very slightly, leaving a little more room for extra water. The result is that the water in the tube falls a little. Very shortly, however, the heat from your hands will have penetrated to the water which will expand and rise up the tube. When you remove your hands from the flask the water and flask will cool and contract and the former will return to its original level.

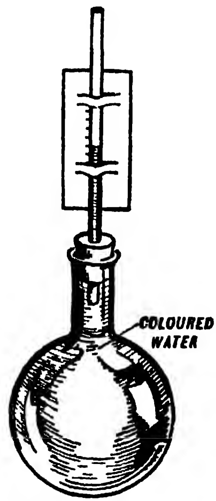


Fig. 43. Apparatus to show that liquids expand when heated.

Although liquids do not expand so much as gases when heated this expansion is easily noticeable.

Do not fill kettles and saucepans too full, otherwise their liquid contents will expand so much when heated that they will overflow.

The expansion of solids

Although the results of the expansion and contraction of solids are, on many occasions, sufficient to fill us with dismay (see paragraph on the expansion of glass), the actual amount of expansion and contraction itself is not often noticeable. To observe the expansion of a poker, for example, we must fix up some apparatus similar to that shown in Fig. 44. The indicator of expansion or contraction consists of a straw or thin wooden splint, through one end of which a needle has been passed. The free end of the poker rests on the needle, and will cause the

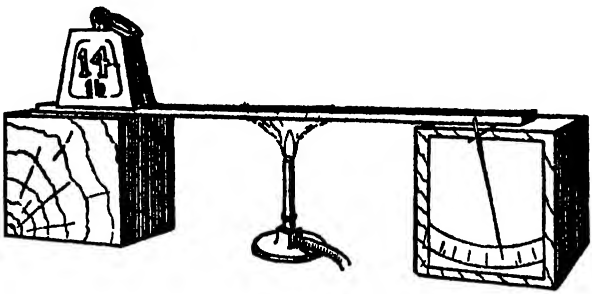


Fig. 44.

needle to rotate one way or another according to whether it is expanding or contracting. The needle makes the indicator rotate with it.

Fix up the apparatus and try the experiment for yourself.

Railway lines

If you have ever examined a railway track carefully you will have noticed that there are small gaps left between the lengths of rail (see Fig. 45). This gap is left to allow for the expansion of the rail during hot weather. The rails are linked together by means of plates provided with oval-shaped bolt holes. These oval-shaped holes allow for both expansion and contraction in the rails. Wooden wedges are driven between the "chairs" and

rails to keep them in position. In very hot weather the iron expands outwards as well as lengthways. At the same time the sun's heat dries up the wooden wedge. Thus the expansion of the iron is allowed for in the shrivelling of the wood.

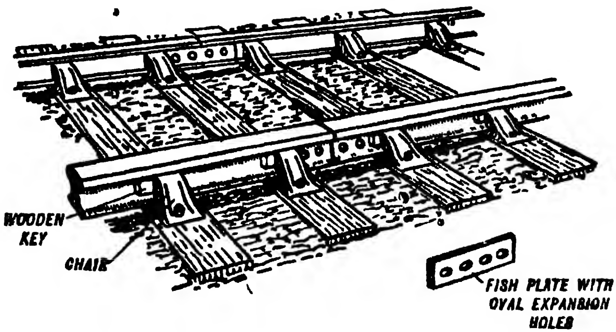


Fig 45. The method of laying railway lines

Steel bridges

When steel bridges are being constructed allowances have to be made for the expansion and contraction of the metal. Generally one end of a bridge is freely supported on rollers. The Britannia Tubular Bridge across the Menai Straits uses this method of allowing for expansion.

Telegraph wires

When telegraph wires are being erected during the summer, it is necessary to make allowances for their contraction in winter. If this were not done, their shrinkage due to the cold weather might cause them to snap.

In summer time the wires will be noticed to sag a great deal.

Why thick glass vessels crack

No doubt many of you have seen a glass vessel broken by having had hot water poured into it. When hot water is poured

into, the glass the inside expands. As glass is a bad conductor of heat, it is some time before the outside of the glass becomes warm.

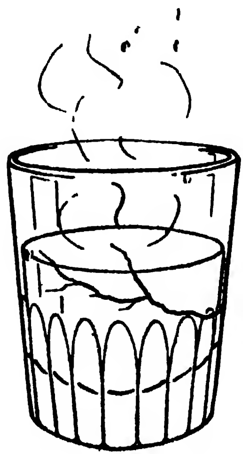


Fig. 46. What may happen if boiling water is poured into a thick glass tumbler

Consequently only the interior of the glass expands. This produces a strain and, more often than not, a crack in the glass.

Riveting

The force of either expansion or contraction is enormous. This force is used to good effect when pieces of steel such as boiler plates are riveted together. The rivet is put into the hole when it is red hot. Whilst it is still hot the rivet is hammered up tightly from both sides. When the rivet cools it contracts and pulls the plates still closer together with such force that the joint is water-tight and steam-tight.

Fig. 47. Showing a hot rivet holding two boiler plates together.

Burst water pipes

You read on p. 25 that water expands when it is cooled from 4° C. to 0° C. Now 0° C. is freezing point and at this temperature water will change into ice. The force of expansion of the water, as it changes into ice, often bursts the pipes that bring the water to our taps. The bursts are not noticed however until a thaw sets in and changes the ice back to water.

Unequal expansions and a fire alarm

Fig. 48*a* shows a compound metal bar held in the clamp of a retort stand. The top layer of metal is made of copper and the

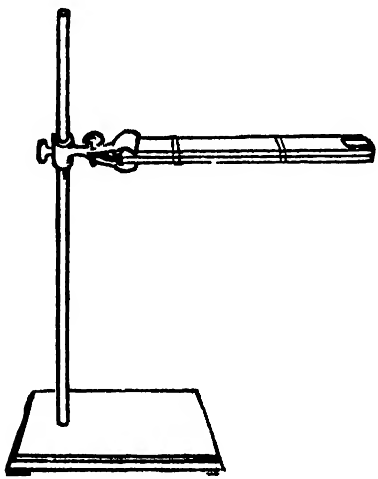
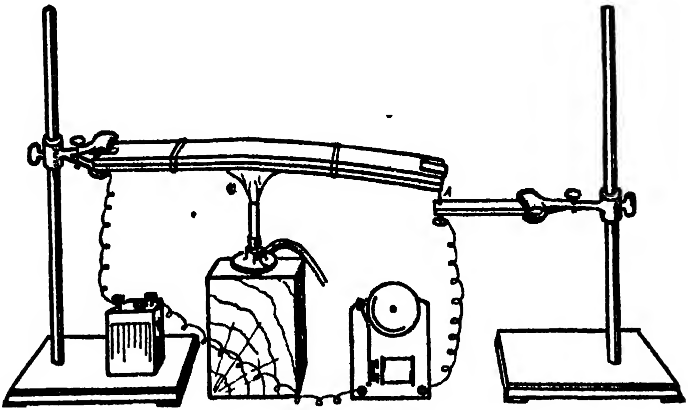


Fig 48*a*

lower one of iron. If this compound bar is heated the copper will expand more rapidly than the iron, so the bar will buckle and bend downwards as shown in Fig 48*b*. By erecting the apparatus shown in Fig 48*b*, you will have a very effective automatic fire alarm. Arrange the apparatus so that when the

compound bar is straight, the point of the nail *A* is about $\frac{1}{8}$ inch away from it. If you warm the bar with your Bunsen burner it will buckle, touch the point of the nail *A* and cause the bell to ring.



MODEL FIRE ALARM

Fig 48 *b*.

Compensated pendulums

Clocks with pendulums keep correct time only if the pendulum always swings at the same rate. In hot weather a metal pendulum will expand and grow longer, which will cause it to swing more slowly and so the clock will "lose time". Again, in very cold weather the pendulum will contract and the clock will "gain time". To avoid all this the pendulum is compensated or counterbalanced. Fig. 49 shows two methods of compensating the pendulum. The figure on the left shows a pendulum in which the mercury expands upwards when the suspending bar expands downwards. The amount of mercury is so arranged that its upward expansion counterbalances the downward expansion of the iron suspending bar. That on the right shows a

pendulum where the brass rods expand upwards the same amount as the iron rods expand downwards.

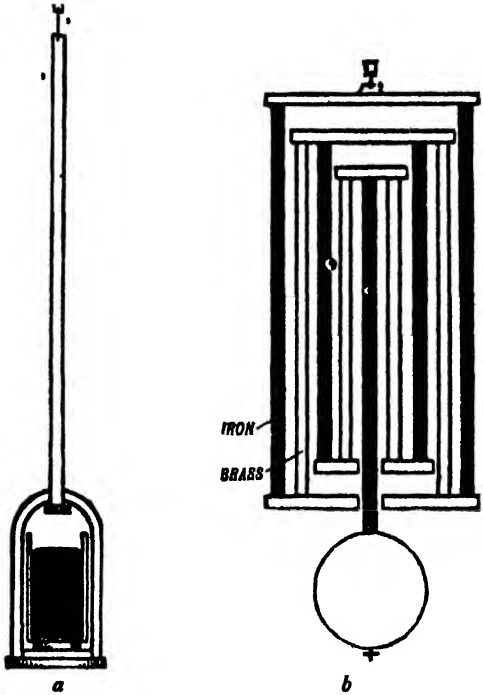


Fig 49 *a*, *b* Compensated pendulums.

Chapter 4

TEMPERATURE AND ITS MEASUREMENT

Temperature

A bucketful of lukewarm water possesses much more heat than a red-hot needle, for the warmth of the water would scarcely be affected if the needle were dropped into it. In spite of this we should say that the needle was very much hotter than the water. In science we should more often say that the needle was at a higher ***temperature*** than the water. Temperature tells us how hot or how cold a substance is, or, as the dictionary might put it, the degree (or amount) of hotness of anything.

Thermometers

Although we ourselves can often give a fair idea of the temperature of anything, it is necessary for us to have some more reliable and accurate means of determining temperature. Instruments which we use for determining temperature are called ***thermometers***. The word "thermometer" is made up from the Greek words ***thermos*** meaning "heat" and ***meter*** meaning "measure".

Most of the thermometers which you will have to use, consist of a closed glass tube with a bulb at one end. Inside the bulb and part of the tube, is a liquid such as mercury and on the tube itself there is a scale. The temperature is read from the mark on the scale to which the mercury rises.

There are two important points on the thermometer scale, viz. the freezing point and the boiling point of water.

Freezing point is obtained by leaving the bulb of the thermometer in melting ice until the mercury remains still. The height of the mercury is then marked on the tube as being freezing point. Boiling point is obtained by leaving the bulb of the thermometer in pure boiling water or, better still, the steam from boiling water.

The Fahrenheit thermometer, invented by a German merchant of Dantzig named Fahrenheit, was the first satisfactory instrument of its kind to be made. He found that freezing point was 32 degrees (written 32°) or divisions above the lowest temperature, which he called 0° or *Zero*, that he could get. This lowest temperature was that of a mixture of salt and melting ice. Fahrenheit found that the temperature of boiling water was 212°.

Since Fahrenheit invented his thermometer a much simpler scale, called the ***Centigrade*** (meaning "100 steps") scale, has been introduced. On the Centigrade thermometer you will find that the freezing point is marked as 0° C. and boiling point as 100° C. Compare the two scales shown in Fig. 50.

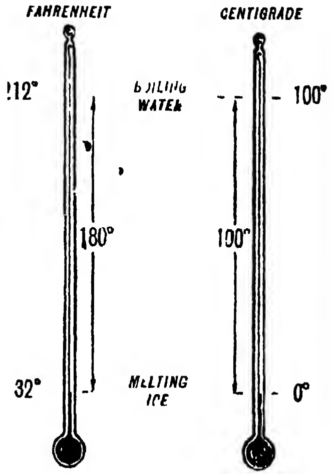


Fig 50 A comparison of the Fahrenheit and Centigrade thermometer scales

Nowadays the Fahrenheit thermometer is mostly used for weather observations and doctors' purposes The Centigrade thermometer is the one mostly used in science laboratories.

The clinical thermometer

The doctor always carries a special type of Fahrenheit thermometer about with him, in order to test the temperature of his patients. It is called a clinical thermometer. The temperature of the body of a healthy person is 98·4° F. During illness a

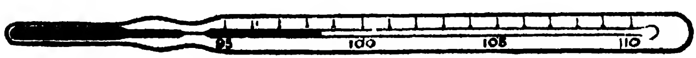


Fig. 51. A clinical thermometer.

person's temperature may go up as far as 104° F. or as low as 96° F.

Because body temperatures seldom go above or below these two temperatures, the scale on a clinical thermometer usually extends from 95° F. to 110° F.

The mercury of a clinical thermometer is so arranged that when it reaches a temperature of about 90° F. it passes through an extremely fine tube into the main part of the stem of the thermometer. The bulb of the thermometer is placed under the tongue or armpit of the patient and when it is removed the mercury remains in the stem, because it cannot pass through the very fine tube into the bulb until the thermometer is shaken. Thus the doctor can read the patient's temperature at his leisure.

Clinical thermometers should not be washed in hot water, otherwise the expansion of the mercury will burst the tube.

Metal thermometers

Metal thermometers are largely used for giving a rough idea of the temperature of the cooling water of a motor-car engine.

A section of one of these thermometers is given in Fig. 52. When the metals become hot they bend towards the left as brass expands more than iron. The subsequent movement of the ratchet causes the small cog wheel, and so the temperature indicator, to move round towards the right. Temperatures can be marked on a glass cover plate.

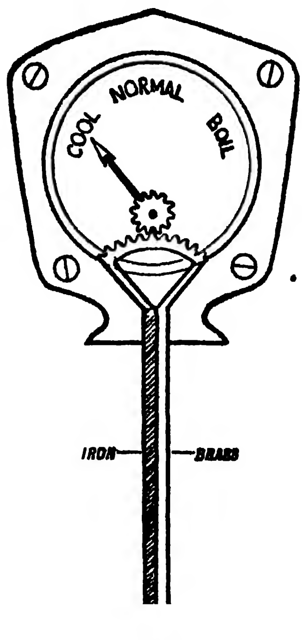


Fig. 52. A metal thermometer

Chapter 5

CHANGES OF STATE AND THE STUDY OF WEATHER

Some further effects of heat on substances

You read on pp. 38–39 that when substances are heated they expand because the molecules of which they are made up are caused, by heat, to move over a wide range. Sometimes, when the heating is sufficiently strong, the molecules are pushed so far apart that the nature of the substance is completely altered—solids become liquids and liquids become gases.

Latent heat

When next you boil some water put a thermometer into it. You will notice that the temperature will go up steadily to 100° C. or 212° F., when the water begins to boil. However much you go on heating the water after it has boiled you will find that you are unable to raise its temperature.

What happens to all the heat given to the boiling water? The extra heat is used up to push the molecules of water so far apart that the water gradually becomes steam. The extra heat is only used up to push the molecules further apart—it does not raise the temperature of the steam at all. As this extra heat does not affect temperature we call it ***latent heat***, which means "hidden heat".

When solids change to liquids, or liquids to gases, they have to be supplied with heat which does not raise their temperatures. This heat is called "latent heat" and is given up again when the gases change back to liquids or liquids to solids.

The following paragraphs will lead you to a fuller understanding of latent heat.

Scalds

A scald caused by steam from boiling water is much worse than one caused by the boiling water itself. This is because the steam ***condenses (changes back to water)*** on your flesh, to which it gives up not only the same heat as the water but also its latent heat, which, in the case of steam, is very considerable.

The scald is caused by the flesh being a bad conductor of heat: in consequence the heat of the water or steam cannot pass away, and so it burns the flesh.

The cooling effect of petrol and ether

If you pour a few drops of petrol on to your hand you will notice that they quickly disappear into the air. (Your sense of

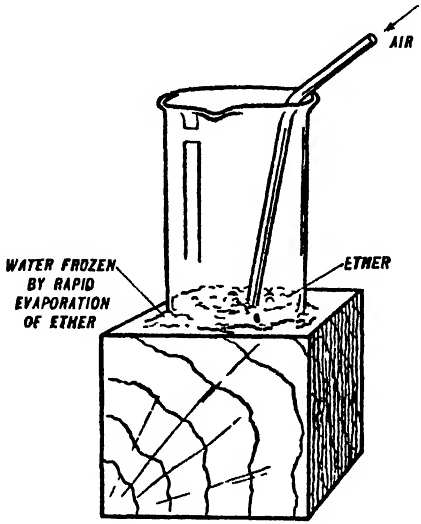


Fig. 53. Liquids that are evaporated will extract the necessary heat from the surrounding objects.

smell will tell you that the liquid petrol has changed into petrol vapour.) At the same time that part of your hand from which the petrol has evaporated will feel cold. You know that all

liquids require an abnormal amount of heat when they change to a gas, and so the petrol has stolen this heat from your hand in order to change it to petrol vapour or gas.

Place a beaker on a block of wood, and pour a teaspoonful of water on the block of wood so that the beaker stands in the water. Pour one or two tablespoonfuls of ether into the beaker.

Cause the ether to evaporate as rapidly as possible by blowing through it a steady current of air. In a short while you will find that the water has changed to ice and frozen the beaker to the block of wood. For its own evaporation the ether took so much heat from the water that the water changed to ice.

Perspiration and chills

When you indulge in exercise, such as running, your body becomes hot and you perspire The perspiration that has formed on your skin will gradually evaporate, but in order to do so it steals heat from your body. This is Nature's method of preventing your body from becoming over-heated. It has one great danger, however. If after violent exercise, during which you have been perspiring freely, you stand about in the open air, the liquid perspiration will take so much heat from your body to turn it into a vapour, that you will most probably take a chill that might have serious consequences.

After violent exercise it is always better to go indoors and have a good rub down or a lukewarm bath.

It is possible to blow your hot tea cold

Although it is not considered good manners to cool hot liquids, such as tea and soup, by blowing them, the blowing will, nevertheless, cause the liquids to cool more rapidly.

The explanation lies in the fact that if the steam hanging over the hot liquid is made to move away rapidly by blowing, then further steam will come from the liquid more rapidly to take the place of that already blown away. The rapid production of the steam takes heat from the liquid more quickly than is normal.

The cooling and warming effects of rain

Rain that falls during the summer cools the air and the earth's surface. Rain or snow that falls during the winter, however, often has a warming effect.

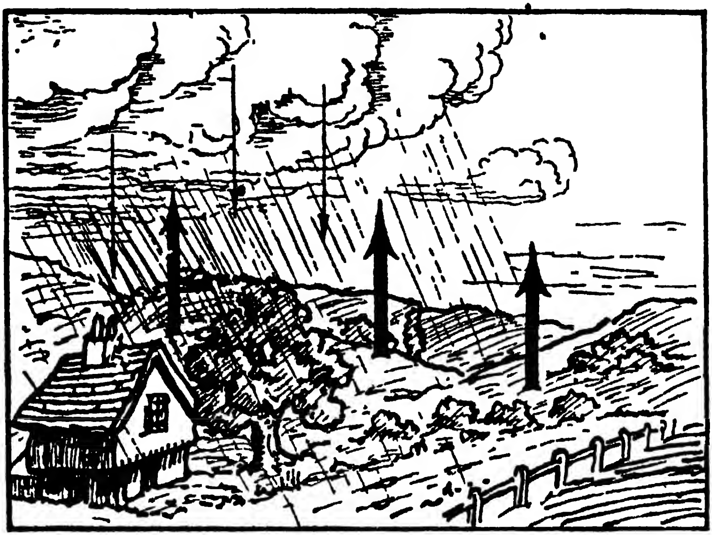


Fig. 54*a*. Summer Rain

Figs. 54*a* and 54*b*. The arrows pointing downwards indicate that heat is being given to the earth by the condensation of the clouds. Those arrows that point upwards show that the evaporation of rain or snow is taking heat from the earth. The thicker the arrow the greater is the speed or rate with which heat is taken from, or given to, the earth.

In the summer, when the water vapour of the clouds condenses and so gives to the air latent heat, the condensation takes place at a normal rate.

The resulting rain quickly evaporates, and rapidly takes heat from the earth's surface. Therefore the earth loses heat for the evaporation more rapidly than it receives it from the condensation (see Fig. 54*a*).

When rain or snow falls during the winter almost the opposite occurs. The air being colder, the condensation of the clouds' water vapour to form rain or snow takes place more rapidly than it does in the summer. Also the subsequent evaporation of the rain or snow that has fallen, goes on very much more slowly than it does in the summer. Therefore, in the winter, the earth gains

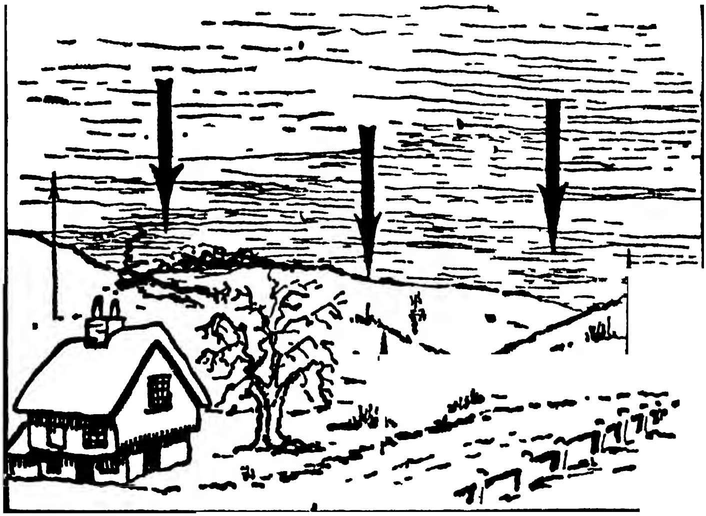


Fig 54 *b*. Winter Snow

heat from the condensation more rapidly than it loses it for the evaporation (see Fig. 54*b*).

Thaws have a cold effect

When snow and ice start to ***melt***, i.e. ***change from a solid to a liquid***, latent heat is required to change their state—solid to liquid—without raising their temperatures. The snow and ice take the necessary heat from the air and earth; therefore thaws make the weather colder.

Mists, fogs, hail, snow, and sleet

Very often, when the weather is cold, the water vapour in the air condenses to tiny particles of liquid, which float in the air as a cloud. A cloud formed in this manner is called a ***mist***. Mists are mostly seen over fields or stretches of water in the early morning, before the sun has had time to warm up the earth. When we set out for school or business on a cold morning, we form small clouds of mist every time we breathe out.

A ***fog*** is really a dense mist, in which the tiny particles of liquid have formed on minute particles of dust or smoke that are always to be found floating in the air, particularly in towns and their immediate neighbourhoods.

Upward currents of air may carry rain-drops to a very great height. At a great height the temperature is very low and the rain-drops are frozen solid. When a solid rain-drop falls again through the clouds, tiny water-drops stick to it and are frozen by it. The resulting lump of ice which falls to the earth is called a ***hailstone***. Hailstones vary in size according to the number of tiny water-drops that freeze on to them as they pass through the clouds on their way to the earth.

When the weather is very cold a rain-drop will freeze almost before it has condensed from water vapour. A beautiful crystalline ***snowflake*** is the result.

Sleet is partially melted snow.

The wet and dry bulb hygrometer

A hygrometer is an instrument used for estimating the amount of moisture present in the air. Fig. 55 shows a popular type of hygrometer known as the wet and dry bulb hygrometer.

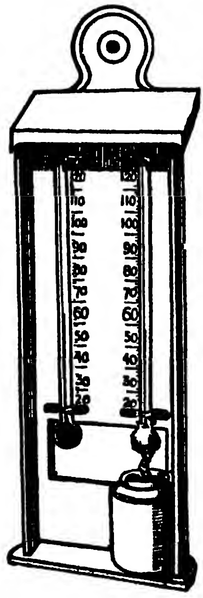


Fig. 55. A wet and dry bulb hygrometer.

The two thermometers, which are alike in every respect, are fixed side by side. Around the bulb of the one thermometer is wrapped a piece of rag, the lower end of which dips into a vessel of water.

The water rises in the rag, like oil in a lamp wick, and keeps the bulb of the thermometer moist. If the atmosphere is very dry moisture will evaporate from the rag and, in doing so, will cool the bulb of the thermometer. As a result, the wet bulb thermometer will indicate a temperature a few degrees below that of its companion, the dry bulb thermometer If, however, the air is full of moisture, as in rainy weather, there will be no evaporation and the two thermometers will read the same.

The readings of the two thermometers of the wet and dry bulb hygrometer give a good indication of the type of weather we may expect. The greater the difference between the two temperatures indicated, the drier will be the weather: if the thermometers give readings which are the same, or nearly the same, damp or rainy weather will be experienced.

Maximum and minimum temperatures

It is an important matter for farmers and gardeners to know what the highest (maximum) and lowest (minimum) temperatures have been during the day and night.

Fig. 56 shows a convenient form of apparatus for obtaining the maximum and minimum temperatures automatically. When the temperature increases the alcohol in the left-hand side of the thermometer expands and pushes the mercury and, therefore, the right-hand indicator, round towards the right-hand side. When the highest temperature has been reached, the indicator, which has a spring (see Fig. 57) to prevent it from returning, remains behind marking the maximum or highest temperature. Meanwhile the alcohol contracts as the temperature falls, and the mercury then retreats and pushes the minimum or lowest temperature indicator up the left-hand side of the thermometer. When the lowest temperature has been reached the indicator is held

in position by a spring, as was the maximum temperature indicator.

The space occupied by the alcohol vapour allows for the expansion in this thermometer. It is similar to the space above the mercury in the ordinary thermometer.

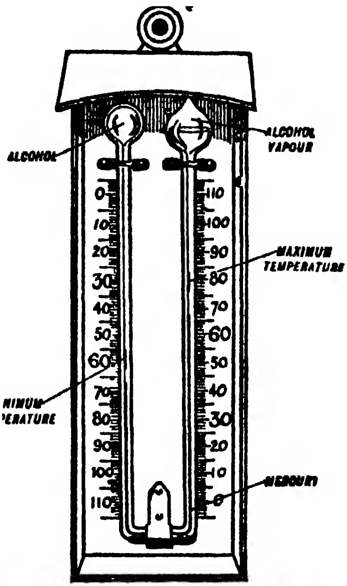


Fig. 56. Six's maximum and minimum thermometer.

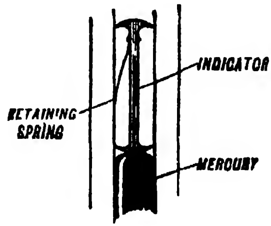


Fig. 57.

The indicators, which are made of steel, are brought back to the top of the mercury in each side of the thermometer by means of a magnet.

A weather prophet

The amount of moisture present in the atmosphere can be roughly indicated by an instrument which depends for its action on a short length of catgut. This instrument is commonly known as a "weather prophet". An illustration of one is shown in

Fig. 58. Such an instrument is fairly easy to make, and Figs. 58 *a* and *b* illustrate how it is to be constructed. One end of the catgut should be fixed to cardboard platform. The other end of the catgut should be glued in position with a piece of cork at the back of the framework (see Fig. 58 *b*). Find which end of

Fig. 58 *a*.

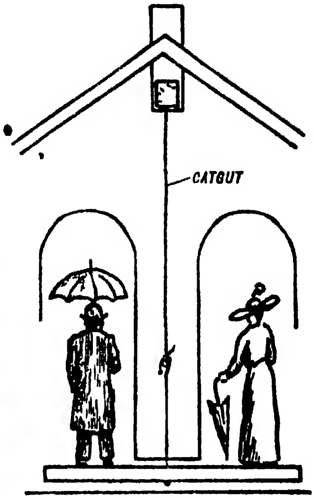


Fig. 58 *b*.

the platform moves forward in damp weather, and on this end fix the man with the umbrella. On the other end fix the woman.

Weather forecasting

Your barometer readings, coupled with those of the wet and dry bulb hygrometer, will give a very accurate indication of the type of weather to be expected immediately.

If the strength of winds and their direction are taken together

THE WEATHER RECORDER

The month of

Hints on weather forecasting

(1) THE BAROMETER If the readings show a rise the weather is likely to improve if th y show a fall the weather s likely to become worse Good weather can be expected if the barometer reading is over 30" bad weather is genera''y experienced when the reading is under 29"

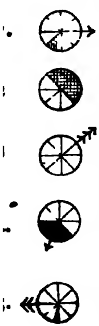
( ) THE WET AND DRY BULB THERMOMETERS If the temperature readings of the two thermometers are the same or very close together, wet weather can be expected Dry weather can be expected if the temperature readings diverge i e go apart

(3) WINDS Westerly or South westerly winds are generally rainbearing winds Easterly winds are dry and cold

K E Y 

The circle is marked off (1) To represent the 24 hours of a day (2) To show the chief points of the compass for marking in the direction and strength of winds.

Suggested method of marking chart



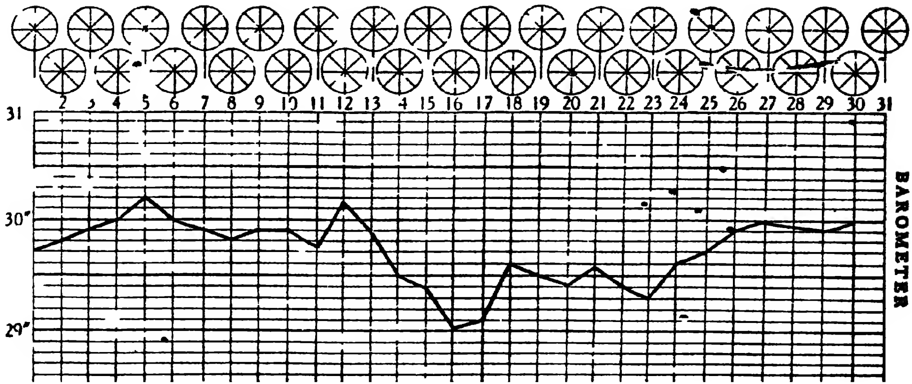
Shows rain from noon till 3. Light W wind

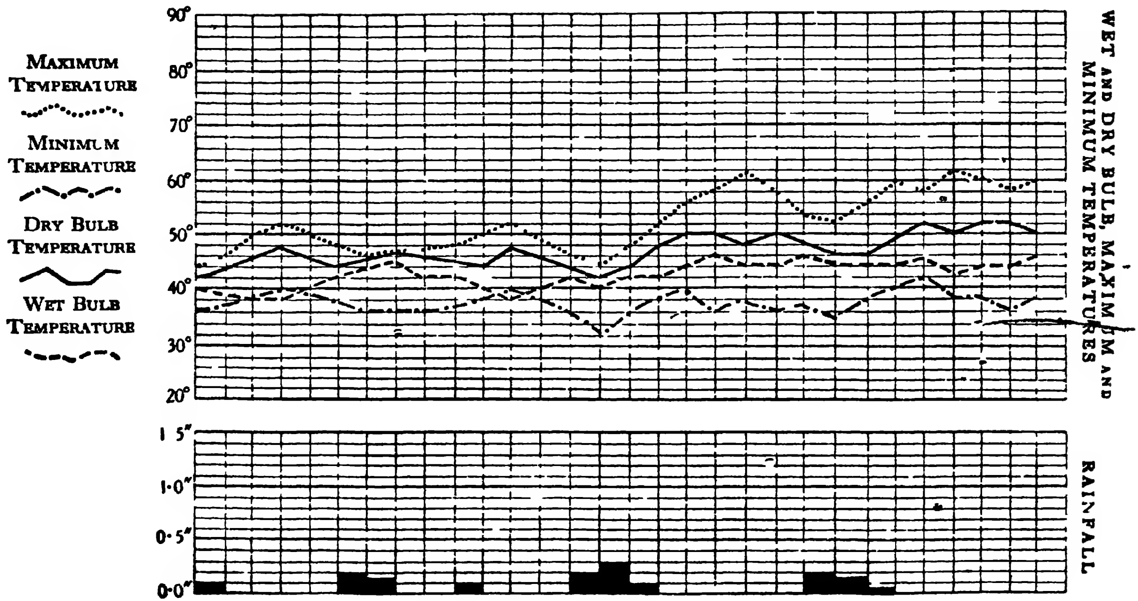
Shows fog from 9 p m till 9 a m

Shows snow from noon till 6 S W gale

Shows sunshine from 9 till 6. Light N N E. wind

Shows hail from noon till 1 Strong E. wind





The month's summary

	Barometer	Thermometer	Rainfall
Highest reading	30·2″	62°	3″
Lowest reading	29″	32°	0″
Mean reading	—	—	—

Total rainfall for the month = 1·55″.

with the daily temperatures and rainfall it is often possible to forecast the weather for several da

Fig. 59 shows a weather chart wi complete daily records for a month. Keep these daily record yourself, and, with the aid of the following hints, prepare your own weather forecast and compare it with that broadcast by the B.B.C. every evening.

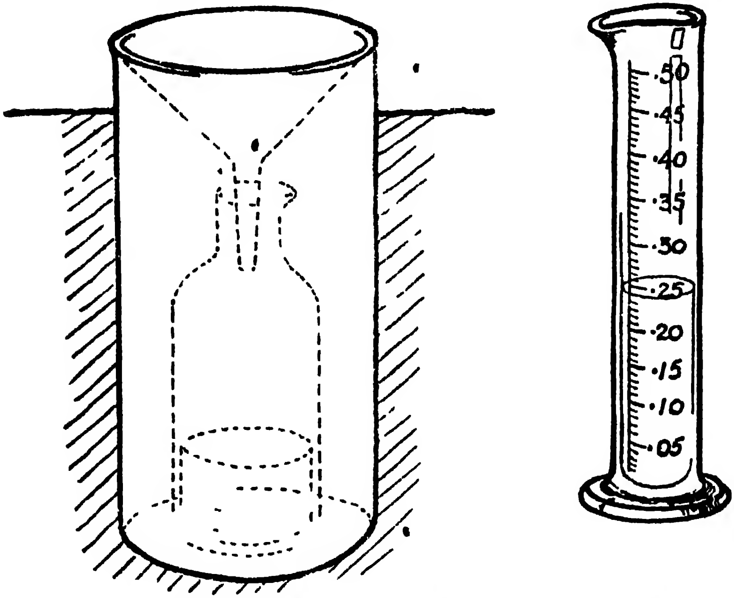


Fig. 60. A rain gauge This should be sunk in the ground until the funnel is about 2 inches above the ground level. The vessel on the right measures (in inches) the quantity of rain that has entered the gauge

The instruments you require for preparing a weather report are a maximum and minimum thermometer, a wet and dry bulb thermometer (this can be made from two thermometers, a piece of bandage, and an ink pot (see Fig. 55)), a rain gauge (see Fig. 60) and a barometer (this can be made—see Book I, p. 11; the mercury should be boiled before it is used to fill the glass tube). The place where these and other weather instruments are

kept is called a ***Meteorological Station*** and the person who prepares the weather forecast is called a ***Meteorologist.***

Hints on preparing weather reports and forecasts

1. The barometer. If the readings show a rise the weather is likely to improve; if they fall the weather is likely to be worse. Good weather can be expected if the barometer reading is over

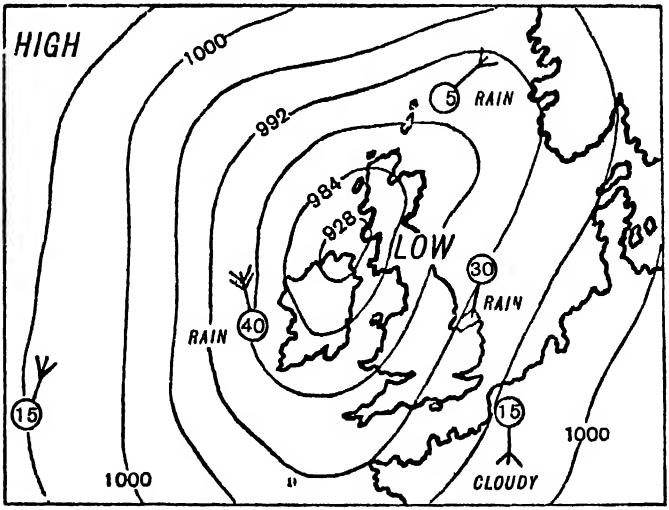


Fig. 61 *a*

Fig. 61 *a, b*. Two weather maps, giving opposite types of weather. The lines on the map are called isobars. They join together places which have the same barometric reading. The winds are strongest in places where the isobars are closest.

30"; bad weather is generally experienced when the reading is under 29".

2. The wet and dry bulb thermometer. If the temperature readings of the two thermometers are the same or very close together wet weather can be expected. Dry weather can be expected if the temperature readings diverge or go apart.

3. ***Winds.*** Westerly and south-westerly winds are generally rain-bearing winds. Easterly winds are dry and cold. Experience in keeping your weather chart records will soon enable you to judge what is to be expected from the various winds.

Winds which are strong when barometer reading is low form what is called a ***cyclone***, and we say that the weather is ***cyclonic***. Cyclonic weather is bad, and in this country does not

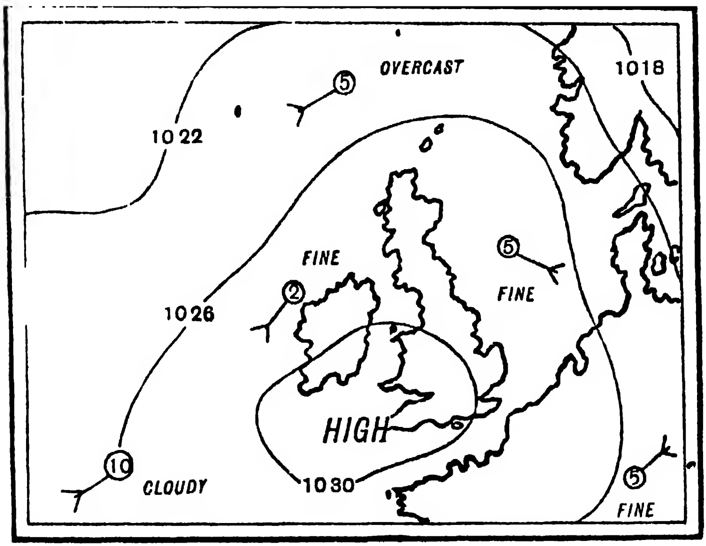


Fig. 61 *b.*

often last more than a day or two, although several cyclones may follow on each other with short bright intervals between them. ***Anticyclones*** and ***Anticyclonic*** weather occur when the barometer reading is high over a large area. In this type of weather the winds are light and dry, and the temperature is low in winter and high in summer. The weather itself may last for several weeks giving rise to a "heat wave" in summer and a "cold spell" in winter.

Fig. 62 shows a piece of apparatus called an ***anemometer***. It is an instrument used for obtaining the velocity, i.e. measuring the speed, of winds.

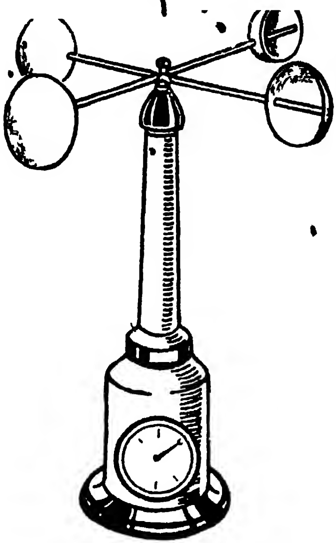


Fig 62. An anemometer. The arms are made to rotate by the wind catching in the cups. This causes wheels inside the instrument to rotate and an indicator shows the velocity of the wind on the dial situated on the side

Summary

Heat, in all its forms, comes directly or indirectly from the sun. It can be produced by friction, explosive mixtures, and the burning glass.

Coal gas, which is a mixture of gases, was first made by William Murdoch towards the end of the eighteenth century.

Nowadays coal gas is made by strongly heating coal in retorts, which are closed vessels to prevent air from getting in and

burning the coal away. The heated coal gives off gases which are first passed through cleansing apparatus and then stored in gas holders.

Coke, left behind in the retorts, and tar and ammonia, obtained from the gas when it is cleansed, are called ***by-products***. Benzol and aniline for making dyes are obtained from the tar.

Coal gas is explosive when mixed with air, highly poisonous, and lighter than air.

A mixture of about one part of coal gas and three parts of air will burn with a hotter flame than the coal gas alone. If too much air gets into the gas, however, the flame will "backfire", or "strike back", or "light back".

Heat travels through solids and so warms them by ***conduction***. All metals, including the liquid mercury, are good conductors of heat. With the exception of mercury, all liquids and gases, clothing material, paper, wood, glass, crockery, bone, and flesh are bad conductors of heat.

Blankets, thatched roofs, mud houses, cooking boxes, the insulated handles of teapots and coffee pots, depend for their existence on their poor conductivities.

The Davy safety lamp and the cooling fins of a motor-cycle engine owe their existence to their good conductivities.

When liquids and gases are heated the particles nearest the heat become warm and rise carrying their heat with them. Other colder particles take their place and become warm and so rise. Thus we get currents which are called ***convection currents***, and the substance is said to be heated by ***convection***. Liquid mercury is also heated by conduction.

Winds and ocean currents are caused by convection.

Our knowledge of convection has been used to provide motor engines with water-cooling jackets and rooms with draught-free ventilation.

Heat can also travel through empty spaces by means of rays. In this case we say that the heat is being radiated. The sun radiates heat to us.

Radiated heat is scarcely felt until after it has fallen on to some non-transparent substance. It is then mostly absorbed if the substance has a dark roughened surface, and mostly reflected if the substance has a white or polished surface.

Most people living in hot countries wear white clothes as the white substance reflects most of the sun's heat. Often they paint their houses white so that the rooms inside shall be cool.

All substances (water between 0°–4° C. is an exception to this) expand when heated and so become less dense and therefore lighter. When cooled, substances contract and so become denser and more heavy.

Gases expand enormously, and whilst the expansion of liquids is quite noticeable, the expansion of solids is so small that it is seldom visible to the naked eye.

Allowances for expansion have to be made when laying railway lines, erecting steel bridges and telegraph wires, and manufacturing pendulums and balance wheels for clocks and watches.

Temperature is a measure of the hotness or coldness of substances. It is measured by means of ***thermometers*** (heat measurers).

The temperature of boiling water is 100° C. (C. for Centigrade) or 212° F. (F. for Fahrenheit). Freezing point, i.e. the temperature of melting ice, is 0° C. or 32° F.

The body temperature of a healthy person is 98·4° F.

Heat, which does not raise the temperature of a substance, is always required to change the substance from a solid to a liquid, or from a liquid to a vapour. On the other hand this same amount of heat is always given up when the substance changes from a vapour to a liquid, or from a liquid to a solid. Such heat is called ***latent heat.***

A person who studies the weather (meteorology) is called a ***meteorologist.***

A ***cyclone*** is a system of strong winds, which occur when the air pressure is low. These winds generally move inwards in a

circle over a large area. Almost without exception they bring bad weather with them.

Anticyclones occur when the air pressure is high. Such winds as occur during an anticyclone are light and dry, and move outwards in a large circle. Anticyclones bring good dry weather which is very cold in winter and very warm in summer.

An ***anemometer*** is an instrument for measuring the velocity of winds.

Questions

1. With the aid of a diagram describe how all our forms of heat—coal, gas, and electric fires—come from the sun. If you can, say how the heat obtained by rubbing our hands together comes from the sun.

2. Describe some method of obtaining heat by friction.

3. Write a short essay on matches.

4. How is gunpowder made? Say how it is that the substances burn rapidly away.

5. Describe carefully how you would use a burning or magnifying glass to set fire to a piece of paper. How does the glass cause the paper to be set alight?

6. Describe the manufacture of coal gas, mentioning the by-products and their uses.

7 Write notes on:

   (*a*) The Bunsen burner, and the two flames it can produce.

   (*b*) The gas ring.

   (*c*) The gas fire.

8. Say what you know about coal gas.

9. What do we mean when we say that a substance is a good conductor of heat? Give another name for a non-conductor of

heat. Write down the names of six good conductors of heat and six non-conductors.

10. Mention one good conductor and one non-conductor that is made use of in everyday life and say how each one works.

11. What is the difference between the conduction and the convection of heat?

12. How can you prove that (*a*) liquids, and (*b*) gases rise when heated?

13 What is a land breeze? Describe how it is formed.

14. Describe the water-cooling system of a motor-car.

15. What is ventilation? How would you ventilate the ordinary room without producing draughts?

16. How does the heat of the sun reach us?

17 The nearer we get to the sun by climbing high mountains or flying upwards the colder we become Why is this?

18. (*a*) Why do people in hot countries wear white clothes?
(*b*) Why is it better to have a polished tea-pot than one with a dull blackened surface?

19. Describe the vacuum flask and say why it can keep hot things hot and cold things cold, for long periods.

20. Explain why substances expand when heated and contract when cooled.

21. Describe how Montgolfier made his balloon ascend.

22. Describe some of the disadvantages of expansion and contraction. Mention one of the advantages.

23. Compare the Fahrenheit thermometer with the Centigrade. Give the names of other thermometers and mention their special uses.

24. What is latent heat? Say why scalds from steam are worse than those from boiling water.

25. What is the chief cause of chills?

26. Why is it cooler after rain in the summer and warmer after rain in the winter?

27. Say how mists, fogs, hail, snow, and sleet are caused.

28. What advice would you give to a person, who was anxious to prepare weather reports and forecasts and who knew little about meteorology?

29. Say what you know about (*a*) cyclonic, and (*b*) anti-cyclonic weather.

Practical Work

A. TITLES OF EXPERIMENTS

The numbers given are those of the pages which will give you the necessary instructions.

The experiments printed in italics are intended for demonstration by the teacher. This is in order either to save time or because the experiments are dangerous.

1. To prepare dilute sulphuric acid. 5.
2. To make old-fashioned "blacking." 72.
3. To set paper on fire with a magnifying glass. (This can only be done when the sun is shining.) 6.
4. To show that the blue cones of the Bunsen flames are regions of unburnt gas. 10.
5. *To show that a mixture of coal gas and air is explosive.* 12.
6. To show that coal gas is lighter than air. 13.
7. To show that mercury is a good conductor of heat. 14.
8. To make and use a paper saucepan. 15.
9. To make a cooking box. 17.

10. To show that wire gauze is a good conductor of heat. 19.

11. To show how water becomes hot. 22.

12. To show that water is a bad conductor of heat. 23.

13. To show what happens to air when it is heated. 24.

14. A radiation experiment with two cocoa tins. 35.

15. Another radiation experiment. 36.

16. To show the expansion of gases. 39.

17. To show the expansion of liquids. 41.

18. To show the expansion of solids. 42.

19. To make a fire alarm. 46.

20. To show that liquids require heat before they can change into a vapour. 51.

21. To make a weather prophet. 59.

B. ADDITIONAL EXPERIMENTS FOR HOME OR SCHOOL

1. How to make a tinder box

A piece of an old file about 2 inches long and an ordinary road flint will be sufficient to produce the spark. The flint may be recognised by the fact that it easily breaks when struck with a hammer, and exposes an almost black surface which has a dull shine.

The sparks are best produced by holding the flint as still as possible and, with a quick downward motion, striking it with the steel.

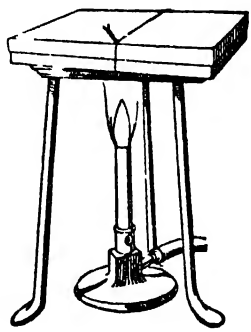


Fig. 63.

The tinder can be made by shutting some pieces of old linen in an air-tight box (an old tobacco tin will do) and

heating the box over the Bunsen flame. It is a good plan to wire the box as shown in Fig. 63. First flames and then smoke will appear. Continue heating until 5 minutes after the smoking has ceased

When you open the tin you will find a black mass of carbon or charcoal the shape of the original linen. The instructions on p. 3 will tell you how to get a flame from the tinder.

2. *Making old-fashioned "blacking."*

Sugar is made up of carbon and water. If concentrated sulphuric acid is added to it the acid will extract the water element, leave behind the carbon and a tremendous amount of heat will be given off.

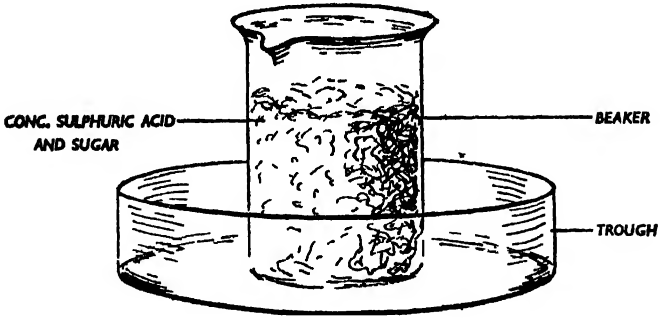


Fig 64.

To a strong syrupy solution of sugar contained in a beaker standing in a trough gradually add a quantity of concentrated sulphuric acid. A black froth containing carbon will swell up and may overflow. Add lime to "kill" any excess acid and old-fashioned "blacking" will result.

3. *To make your own coal gas*

Pack finely divided coal into an old clay pipe and plug up the bowl with clay. Strongly heat the bowl and if the clay cracks

replug it. After a while light the gas issuing from the mouthpiece.

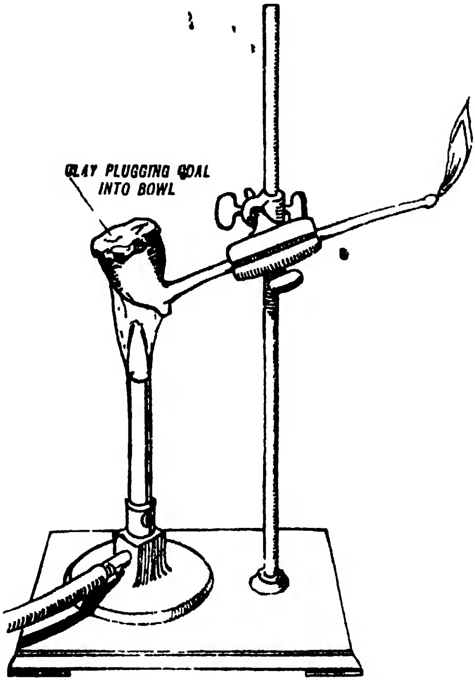


Fig. 65.

4. *To make a manometer*

A manometer is an instrument for measuring the pressure of gases.

Bend a piece of glass tubing into a U shape and partly fill it with coloured water. Mount the tube on a stand as shown in Fig. 66, and between the two limbs place a scale marked off in inches and fractions of an inch.

5. *To measure the force at which the gas is supplied*

By means of a piece of rubber tubing connect one end of your

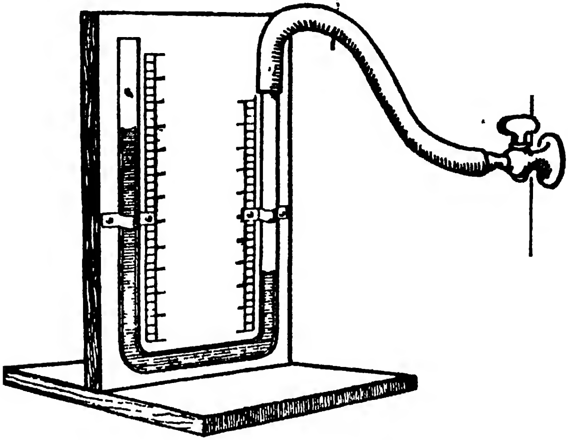


Fig. 66. A manometer connected by rubber tubing to a gas tap.

manometer to the gas tap. Gradually turn the tap until the gas is full on. Read the difference between the levels of the two limbs of the tube, and then work out the pressure of the gas. 1 inch of water = one twenty-seventh pound per square inch (approx.).

6. *To show that the interior of the blue cone of a Bunsen flame is cold*

Push a pin through a match just below the head. Arrange it in the very centre of the Bunsen tube as shown in Fig. 67. Turn on the gas and ignite it. Neither match head nor stalk will burn.

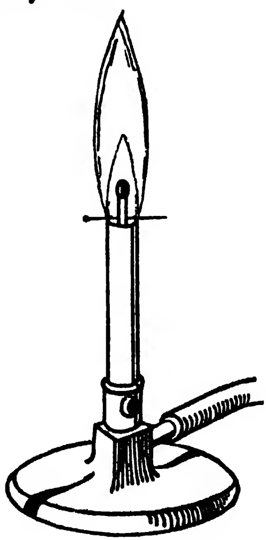


Fig. 67.

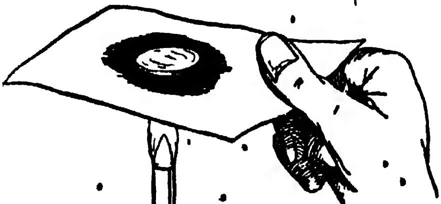


Fig. 68.

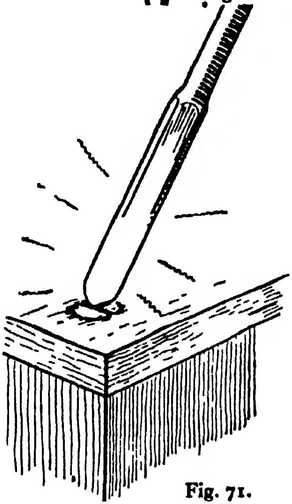


Fig. 71.

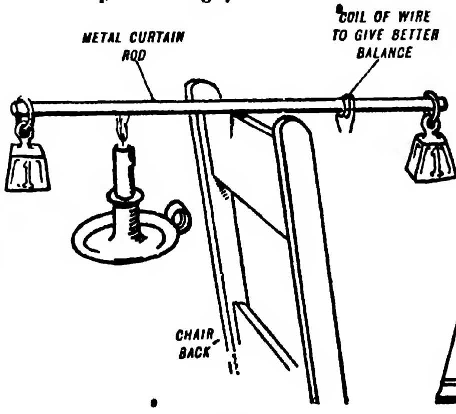


Fig. 70.

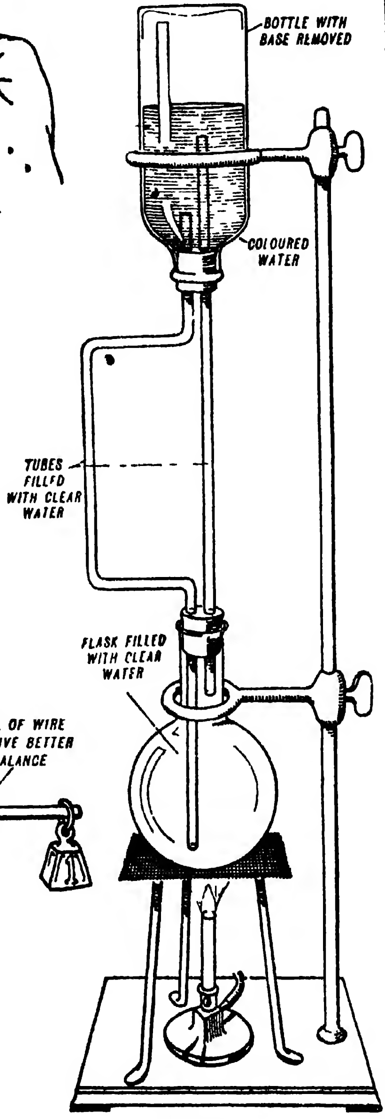


Fig. 69.

7. *A conduction trick*

Put a coin on a piece of paper and move it about above a Bunsen flame so that it will not take fire. When the paper is well scorched remove it from the flame. The part of the paper that the coin had occupied will be found to be unscorched. This is because the coin had conducted most of the heat away (see Fig. 68).

8. *A model to show how hot-water heating systems work*

Fix up the apparatus as shown in Fig. 69 and heat the flask by means of the Bunsen flame. Notice the direction of the flow of the coloured water.

9. *An expansion trick*

Carefully balance a metal rod such as a curtain rod on a chair back by means of weights. A perfect balance can be obtained by carefully sliding a coil of copper wire along the rod (see Fig. 70).

Now heat one side of the rod by means of a candle flame. In a short while the side that is being heated will overbalance the other This is because the heated side expands slightly and so grows a little longer. This very slight extra length gives it a little more leverage and so causes it to overbalance the cold side.

10. *Removing a rusty screw by expansion*

Apply the end of a red-hot poker to the head of the screw for a minute. The screw should then be able to be removed (see Fig. 71).

11. *To show the unequal expansion of metals*

Take two pieces of wire, one of copper and one of iron, each about one foot long. Twist their ends together as shown in Fig. 72 so that both wires are parallel. Hold the wires in a flame and notice the change that takes place.

Fig. 72

Section II. WORK AND MACHINES

Chapter 6

WORK AND SIMPLE MACHINES

Work

Many people would be filled with dismay if they were suddenly ordered to do some hard work and yet this afternoon quite a number of my schoolgirls have been working really hard in the schoolyard during their break or recreation period. Furthermore they seemed thoroughly to enjoy this work, which consisted of nothing more than skipping. Perhaps you will say that these girls were not working but playing. In science, however, we say that ***whenever an object is moved work is done***. The girls have actually done work by jumping up and lifting their bodies off the ground.

The amount of work done in lifting an object is measured by multiplying the weight of the object by the distance it is lifted up. If a brick weighing 2 lb. is lifted 3 ft., then the work done is 2 lb. $\times$ 3 ft. = 6 ft.-lb.

Nowadays most of the work that is being done in moving objects from one place to another comes from machines of various kinds, but in very early times such work had to be done either by mankind or by animals trained by mankind.

What makes work hard?

(i) ***The force of gravity.*** This force which pulls all things down to the earth's surface makes it difficult for us to lift and move objects from place to place. On the moon the work of lifting or climbing would be easier than it is on the earth because the gravitational pull (see Book I, Chapter 11) of the moon is only one-sixth that of the earth.

(ii) ***Friction.*** Friction is the rubbing of two bodies one against the other. Friction makes work harder owing to the fact that rubbing causes loss of power. A motor-car loses some of its

speed because it has to push against the air and rub its way through it. Meteorites become white hot and so visible to the naked eye partly owing to the friction set up between themselves and the air as they rapidly pass through it.

Most of the power used to propel a ship is used up in overcoming the friction between the sides of the ship and the water. Aeroplanes are much more speedy than motor-cars chiefly because the friction between the road and tyres of the motor-car is done away with in the case of the aeroplane.

It is very much better to move a load of bricks by carting them away in a wheelbarrow (see p. 84, Fig. 83) than by sliding them along the ground in a flat box. In this latter case the whole of the bottom of the box, which is rough, is rubbing against the ground while in the case of the wheelbarrow only one part of the smooth wheel at a time is coming into contact with the ground.

Friction increases with

(*a*) The roughness of the rubbing surfaces.

(*b*) The weight of the uppermost body.

In all the machines mentioned in the following pages there is a certain amount of work wasted owing to the friction which has to be overcome. This friction can be reduced, however, by oiling.

Fig. 73. If the boy in this figure were standing on a frictionless floor with perfectly frictionless bottoms to his shoes (which is, of course, impossible) his only satisfactory method of moving would be by blowing. He would then move backwards just as a rocket goes upwards as long as it fires downwards.

The amount of friction between the surfaces of different substances varies. Iron on brass gives very little friction and so steel axles are frequently to be found running in brass sockets or bearings.

At times, friction can be very helpful to us. When we walk, the friction between our shoes and the pavement enables us to push forward. Compare this with the case of the boy in Fig. 73.

Brakes depend for their action on friction between the brake blocks and wheel rims.

(iii) ***Inertia.*** Inertia is the powerlessness of anything to move if it is at rest, or to change its speed if it is in motion, unless it is made to do so by some outside force. This can be illustrated by taking a short journey on a tram or 'bus whilst supporting yourself from one of the straps for standing passengers. When the tram or 'bus moves, your body, being powerless to move of its own accord, tries to remain where it was, and so you

TRAM STARTS SUDDENLY

Fig. 74.

lurch backwards (see Fig. 74). Again, when the 'bus is travelling at twenty miles an hour so is your body, and your body, possessing inertia, is powerless to stop of its own accord. Therefore when the 'bus is brought suddenly to a standstill your body tries to travel on. This makes you lurch forwards (see Fig. 75).

When work is being done in moving an object some force is always used up in overcoming the inertia of the object. Once the inertia has been overcome less force is required as the work becomes easier. The inertia of a 'bus and all its passengers requires a great effort from the engine to set them all in motion,

but when they are all going at a speed of say fifteen miles an hour less engine effort is required to keep this speed up.

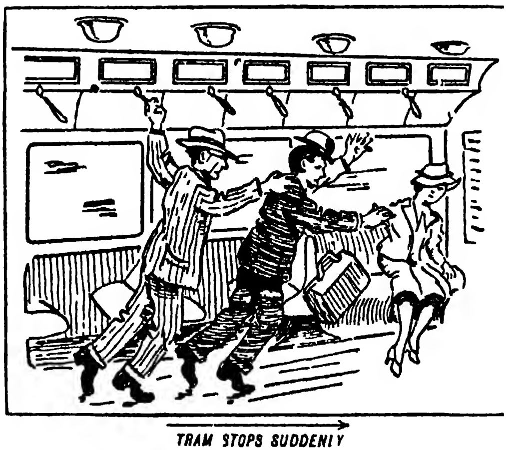


Fig. 75.

Simple machines that have been invented to make work easier

1. ***The lever.*** A lever is generally a stiff rigid rod. A ***crowbar*** is one of the simplest of levers. Fig. 76 illustrates a crowbar

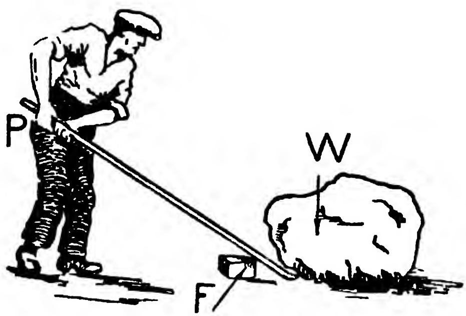


Fig. 76.

in use. The point (F) where the lever is always at rest is known as the ***fulcrum*** or point of balance: the object to be moved (W)

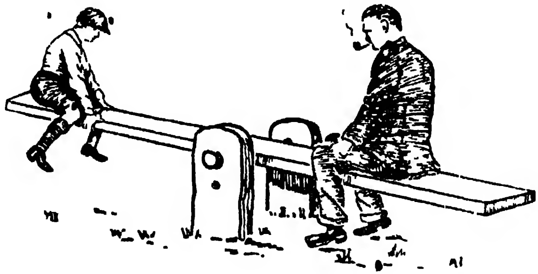


Fig. 77. In order to enjoy a game of seesaw on a 12 ft. plank with a 6 stone boy sitting on one end, a 12 stone man would have to sit 3 ft. from the centre or fulcrum.

is referred to as the ***weight*** or ***load***; and the force (P) used to lift the huge stone is known as the ***power***. The ***mechanical advantage*** or saving of labour or ***leverage*** of a lever depends upon the lengths of the arms, i.e. the distances from F to W and F to P. The leverage of the crowbar

$$= \frac{\text{Length } PF \text{ (5 ft.)}}{\text{Length } WF \text{ } (\tfrac{1}{2} \text{ ft.})} = 10.$$

From Fig. 77 you will see that

Weight × its distance from fulcrum = Power × its distance from fulcrum.

Therefore in order to move the stone the man in Fig. 76 would only have to exert a force just a little more than one-tenth the weight of the stone.

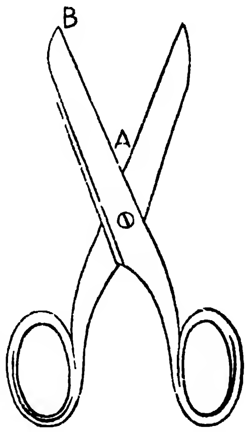


Fig. 78. A pair of scissors consists of two levers. If the object to be cut is put nearer to A than to B, less work will have to be done in cutting it.

Pairs of scales, scissors, and shears; steelyards, wheels, lock gates, door knobs, and the two halves of the Tower Bridge

in London, are examples of levers such as we have been describing.

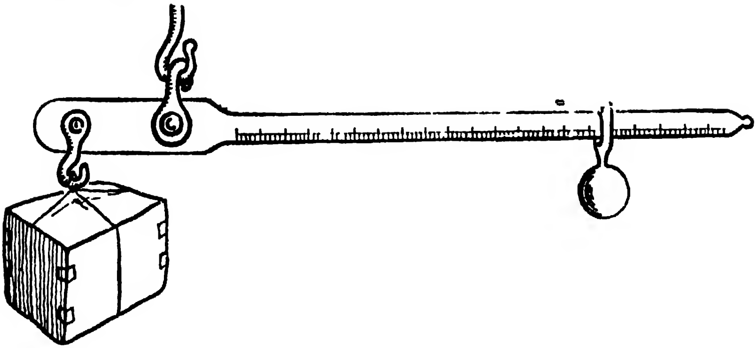


Fig. 79. Weighing by means of a steelyard.

The wheel and axle. Fig. 80 illustrates a device known as the wheel and axle. The mechanical advantage of this machine is equal to

$$\frac{\text{Distance } PF \text{ (power arm)}}{\text{Distance } WF \text{ (load arm)}}.$$

In this particular case the mechanical advantage is 2, i.e. a force of only 56 lb. is required to balance the weight or load of 112 lb.

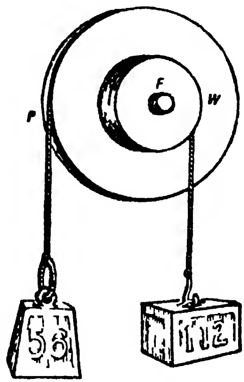


Fig. 80. A wheel and axle.

The capstan is a form of wheel and axle. The weight or load is taken up by the rope which is wound on to the narrow trunk

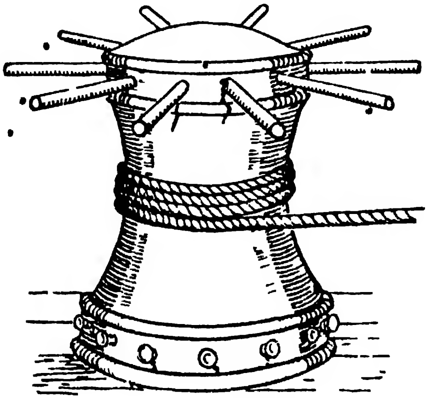


Fig 81. A capstan.

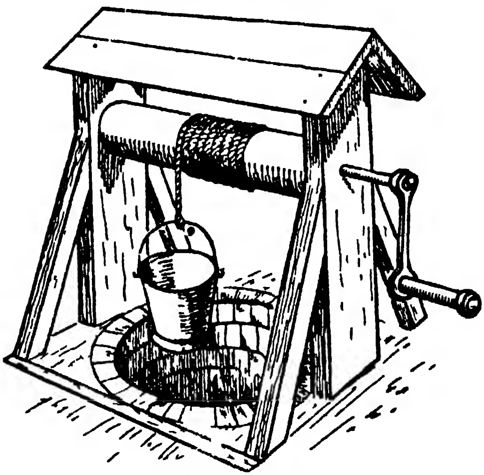


Fig. 82. A winch.

of the capstan. Tremendous force is obtained when all the spokes are manned as the ends of these spokes are much further from the centre of the capstan than the wound rope.

Another form of the wheel and axle is the ***winch*** such as is used for raising buckets of water from a well.

The wheelbarrow is a form of lever which is balanced at one end (the wheel) with the load between the fulcrum or balance point and power point (see Fig. 83).

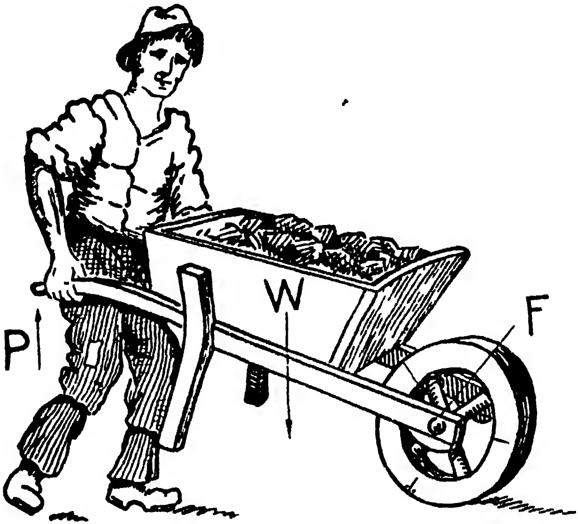


Fig 83.

Nutcrackers consist of a double lever each one similar to the wheelbarrow The nut is the load, the fulcrum is where the two

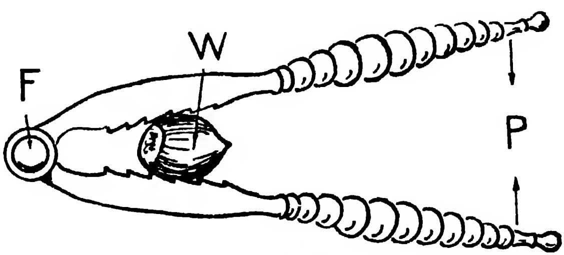


Fig. 84.

arms are joined, and the power is applied at the free ends of the arms.

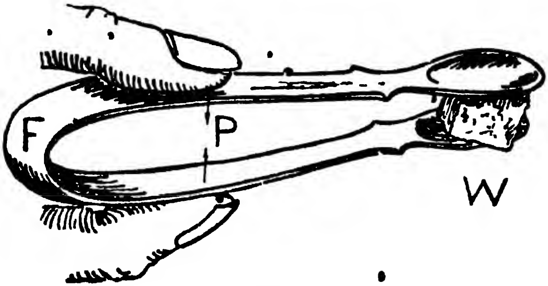


Fig. 85.

Sugar tongs are levers which are different in type from the crowbar and the wheelbarrow. Here, from Fig. 85, you will see that the power is in between the weight or load, i.e. the sugar, and the fulcrum.

2. ***Pulleys.*** Every pulley wheel is a lever, but sets of these pulleys can be combined and used together to make one piece of work very much easier to perform.

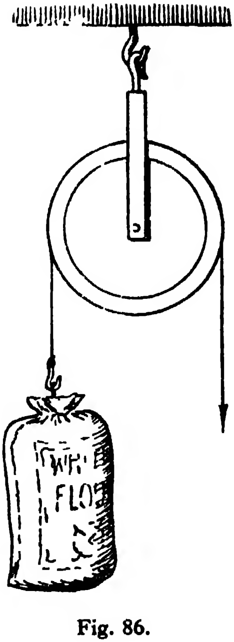


Fig. 86.

Fig. 86 shows a single pulley with which just as much force is required as would be needed if the sack were raised off the floor with the hands. The pulley is merely a convenient method of raising the sack to a required height.

If two pulleys are used as in Fig. 87 the movable pulley and the sack have to be raised. The force required, however, to do the work of lifting this load is less than that required to lift it by the hands. A man who could just lift 1 cwt. with only

his hands would be able to lift almost 2 cwt. with the arrangement of pulleys shown in Fig. 87.

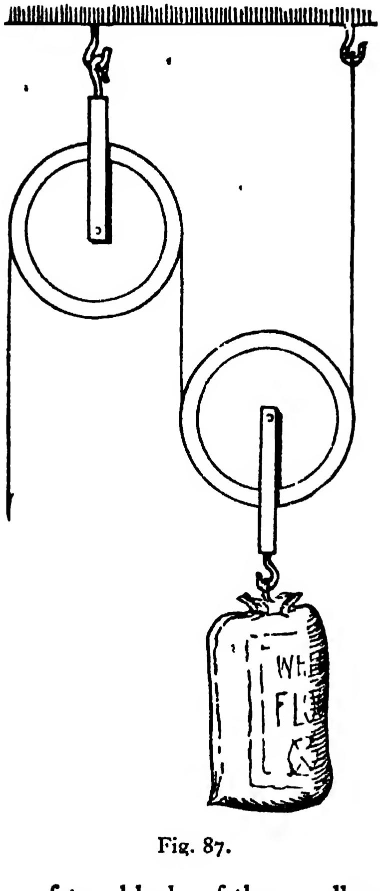


Fig. 87.

A combination of two blocks of three pulleys each, arranged as in Fig. 88, is the most common system of pulleys for raising huge weights with a small force. The supporting rope is attached to the bottom of the top block and passes round each pulley in turn. The mechanical advantage of this arrangement

of pulleys is equal to the number of strings supporting the bottom block, viz. 6. That is to say, the man mentioned in the previous paragraph would be able to raise almost 6 cwt. with it.

It should be noted that the amount of work done (weight of object × distance it is moved) by whatever method is always the same, for in order to raise the weight on the bottom block 1 ft. (Fig. 88) the pulling rope has to be hauled in 6 ft. The mechanical advantage arises from the fact that a force only about one-sixth of the weight being lifted is required for the operation with the pulley blocks mentioned above.

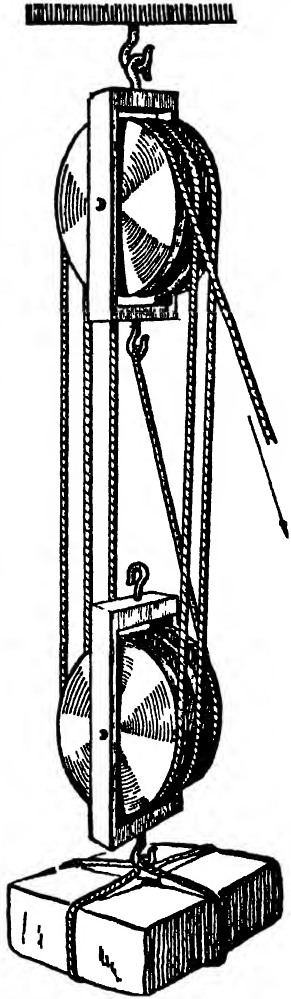


Fig. 88.

3. The inclined plane. Everyone knows that it would be easier to push a loaded wheelbarrow up a gradual slope than up a steep one of the same height. The mechanical advantage of an inclined plane is obtained by dividing the length of the plane by the vertical height that the plane reaches. Thus in Fig. 89 the mechanical advantage of slope $AB = \frac{150 \text{ ft.}}{100 \text{ ft.}} = 1\frac{1}{2}$, that of slope $BC = \frac{300 \text{ ft.}}{100 \text{ ft.}} = 3$.

The Pyramids of Egypt, built thousands of years ago from enormous blocks of stone, are almost 400 ft. high. It is a source of wonder to the people who visit the Pyramids as to the methods the ancient peoples

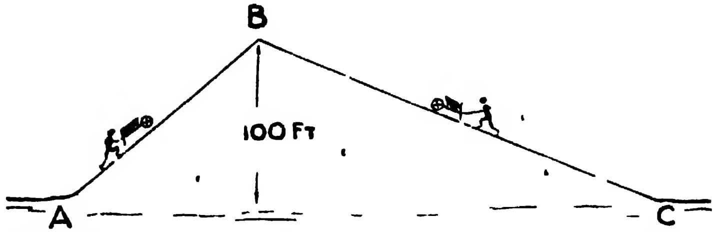


Fig. 89 Two boys pushing similar wheelbarrows equally loaded up a hill If distance AB is 150 ft and BC 300 ft, then the boy ascending the latter slope has to exert half the force in pushing his wheelbarrow that the other boy exerts for the same result The boy ascending BC, however, has to exert his half force over twice the distance that the other boy covers

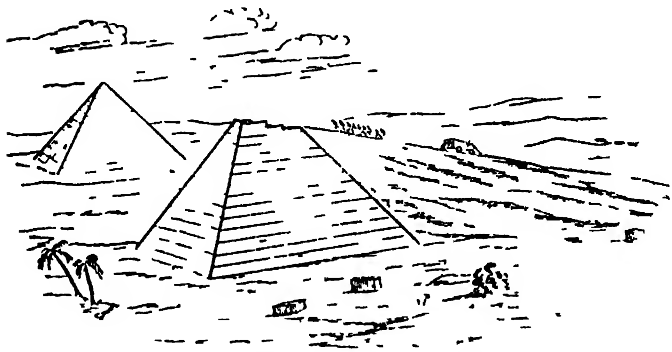


Fig. 90. How engineers believe the pyramids of Egypt were built.

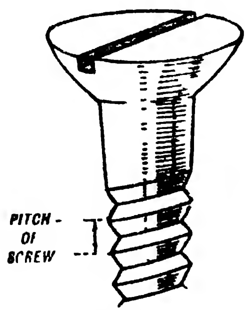


Fig 91

adopted to raise these enormous blocks of stone to the necessary height. Many people believe that the huge blocks of stone were transported on rollers up long inclines of earth built up against the Pyramids (see Fig. 90).

A ***screw*** is a form of inclined plane and the track of the incline round the screw is called the ***thread***; the distance between one turn and the next is called the ***pitch***. The mechanical advantage of a screw

$$= \frac{\text{Distance covered by one complete turn of thread}}{\text{Pitch}}.$$

4. ***Gears.*** Gears consist of wheels of different sizes which are joined together by chains or brought into contact with each

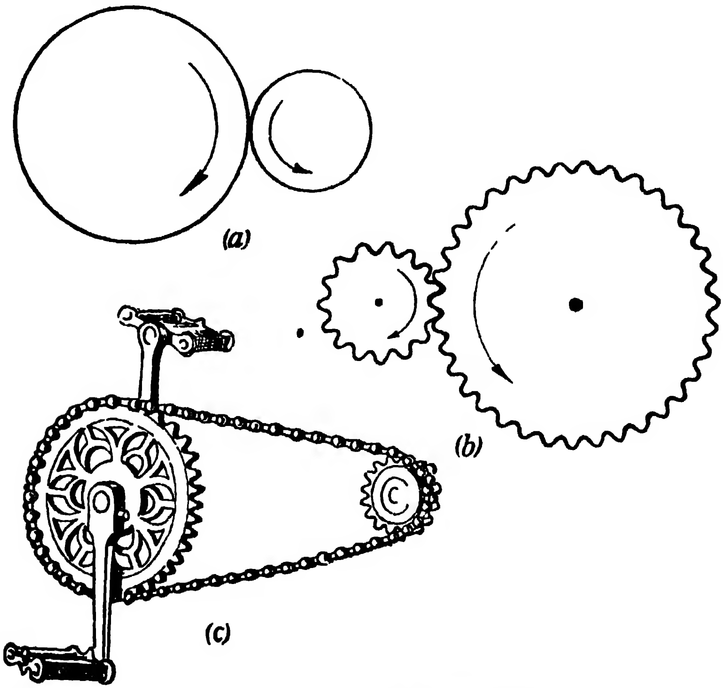


Fig. 92. Different types of gear wheels.

other, so that when one of the wheels is rotated or made to turn round then the other wheel also rotates but at a greater or smaller speed.

In Fig. 92 *a* and *b* the one wheel causes the other to rotate by means of either friction or the cogs. In Fig. 92 *a* the mechanical advantage of the gear system

$$= \frac{\text{Diameter of turning wheel}}{\text{Diameter of wheel that is turned}};$$

in other cases the mechanical advantage

$$= \frac{\text{Number of cogs on turning wheel}}{\text{Number of cogs on wheel that is turned}}.$$

Chapter 7

ENGINES

Steam

Often, when the kettle is boiling, the lid bobs up and down. It is lifted by the force of the steam coming from the boiling water. The following simple experiment can be performed to show the enormous force possessed by steam coming from boiling water. Partly fill a small tin can, such as painters use, with water and tightly cork it up. Now heat the tin can over a burner and stand well back. Soon the water will boil and the force of the steam will become so great that either the cork will be blown out or the tin will burst.

Clever men have invented various kinds of engines which use this steam force or pressure to do useful work.

How the toy steam engine works

Steam is generated or produced in the boiler and is carried by a pipe to the plate pierced with three holes, see Fig. 94. At

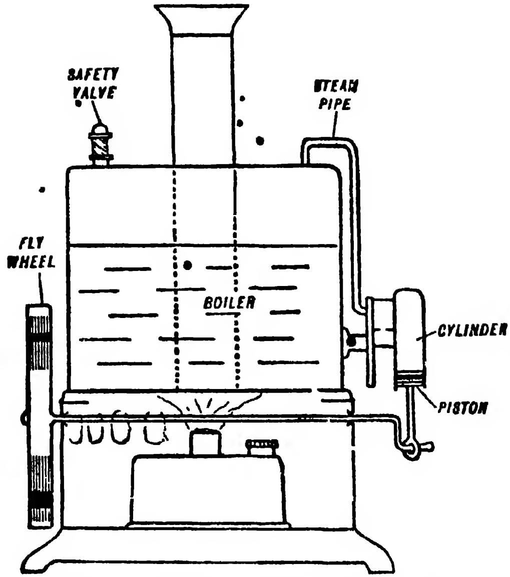


Fig 93. A section of a toy steam engine.

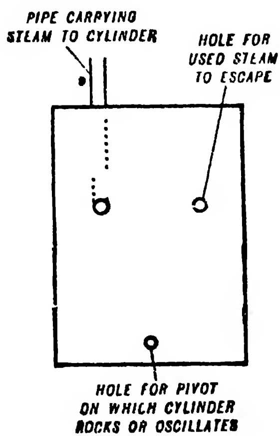


Fig. 94.

the back of the cylinder is a hole which, in Fig. 95 *a*, coincides with the steam inlet. When in this position steam enters the cylinder, blows the piston downwards and so causes the fly-wheel to rotate or turn round. The turning of the fly-wheel causes the cylinder to move over into the position shown in Fig. 95 *b* when

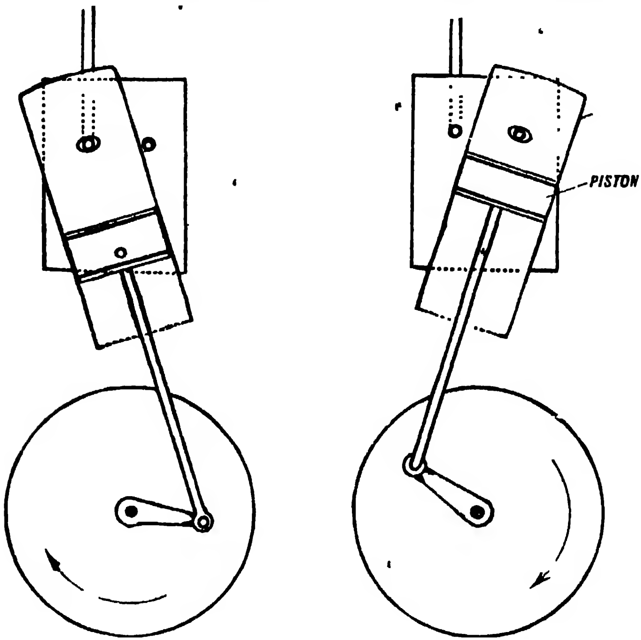


Fig. 95.

the piston ascending pushes the used steam out of, what is called, the exhaust hole. Further rotation of the fly-wheel brings the cylinder back to the first position for more steam and so it goes on.

The steam engine used in locomotives

The general arrangement for producing steam in this type of engine is shown in Fig. 96. From the fire box hot fumes pass

along the many fire tubes which run from end to end of the boiler.

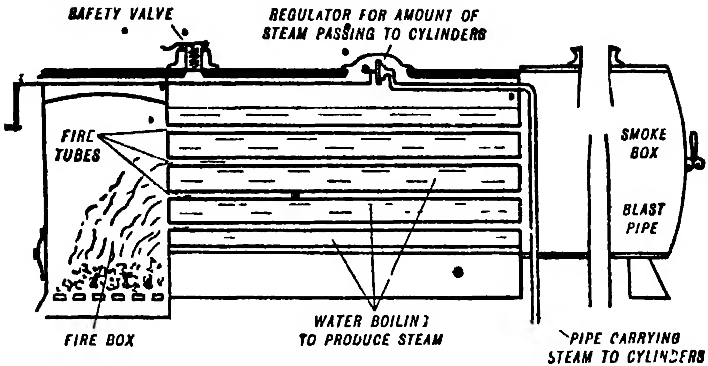


Fig. 96. Diagram of a locomotive boiler.

The amount of steam which passes along the pipe to the cylinders is controlled from the cabin by means of a rod.

The inside of the steam-engine cylinder is shown in Fig. 97. In Fig. 97 steam entering the cylinder passes along the left-hand steam passage and causes the piston to travel to the right. As the piston does this it pushes the steam on its right up the right-

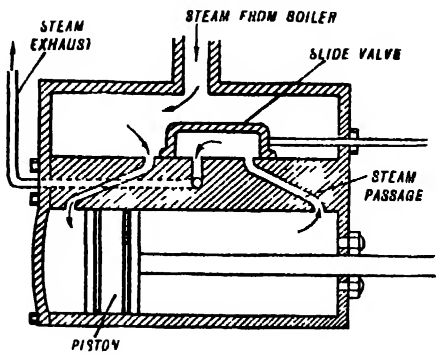


Fig 97. Diagram of the cylinder of a locomotive.

hand steam passage and out through the steam exhaust. When the piston has travelled as far as it can to the right, the slide valve moves to the left leaving the right-hand steam passage open and covering up the left-hand one. Steam now passes down the right-hand steam passage causing the piston to travel to the left.

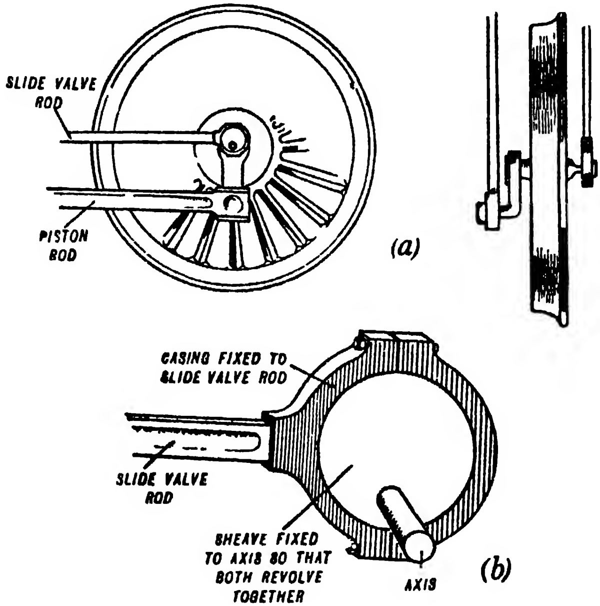


Fig. 98. Showing (*a*) how the piston turns the wheel and (*b*) how the wheel works the slide valve.

As it does so the steam on its left is pushed up the left-hand steam passage and so out through the exhaust.

These operations are repeated continuously. The to and fro movement of the piston is made to turn the wheels of the locomotive by an arrangement illustrated in Fig. 98. The piston is joined to the wheel by a connecting rod and crank. The slide valve is made to move to and fro by being connected to an

eccentric, i.e. a bearing which is not placed centrally in the wheel.

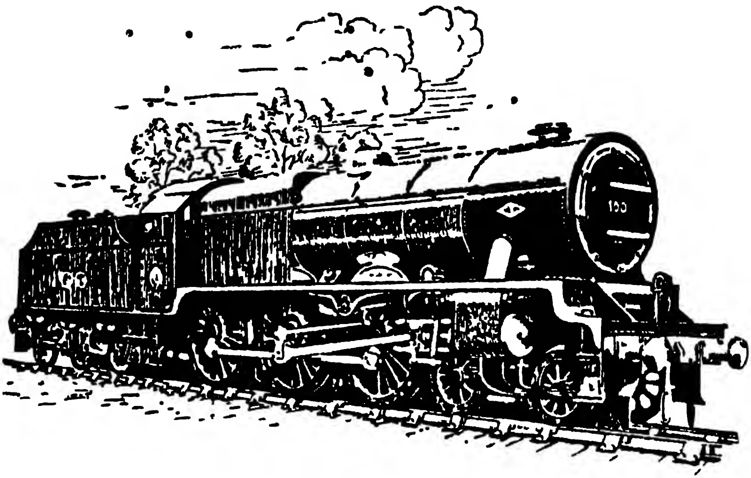


Fig. 99. A railway locomotive.

The internal combustion engine

Internal means inside, and combustion means burning. In the steam engine all the necessary burning takes place outside the engine in the open firebox. We are now going to study engines for which all necessary burning takes place inside the engines themselves: in other words we are going to study internal combustion engines. Most of these engines burn petrol as fuel, some burn coal gas, and others oil.

The four-stroke internal combustion engine

An illustration of the working parts of this type of engine is given in Fig. 100. It is called a four-stroke engine because the piston has to make four particular movements or strokes up or down the cylinder before the set of operations necessary for the running of the engine is completed.

In order to start the engine on its first four strokes the fly-wheels are first made to go round by the self-starter (motor-cars), or the propellor on aeroplanes.

The four essential or necessary strokes are given below.

1. The inlet or suction stroke (see Fig. 100). As the piston descends the inlet valve opens and petrol vapour together with air are drawn into the cylinder.

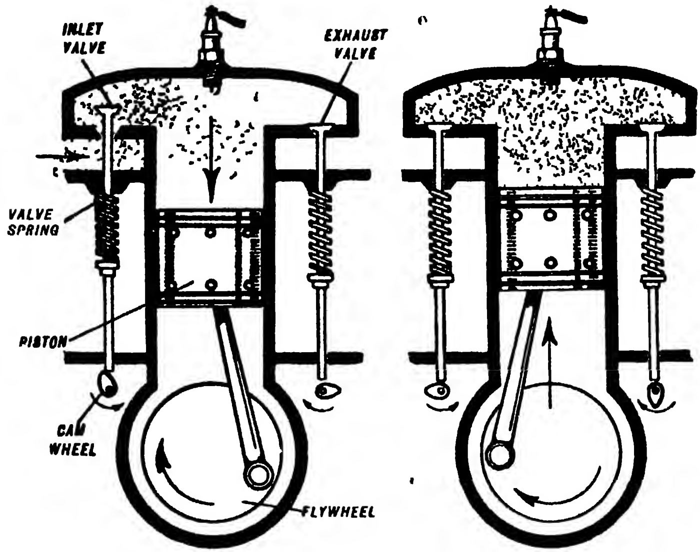


Fig. 100 Fig. 101.

Fig. 100. A section of the four-stroke engine during the inlet stroke
Fig. 101. A section of the four-stroke engine during the compression stroke

2. The compression stroke (see Fig. 101). The fly-wheel still revolving causes the piston to rise in the cylinder and as both valves remain closed throughout this stroke then the gases are squeezed together or ***compressed*** in the top of the cylinder.

3. The power stroke (see Fig. 102). Immediately the compression stroke is finished an electric spark is produced between

the points of the sparking plug. This spark explodes the gases. The explosion, and so rapid expansion of the gases, forces the piston down again. It is this stroke which gives the engine its power. The power with which the piston is forced down during this stroke must cause the fly-wheel to travel with at least suffici-

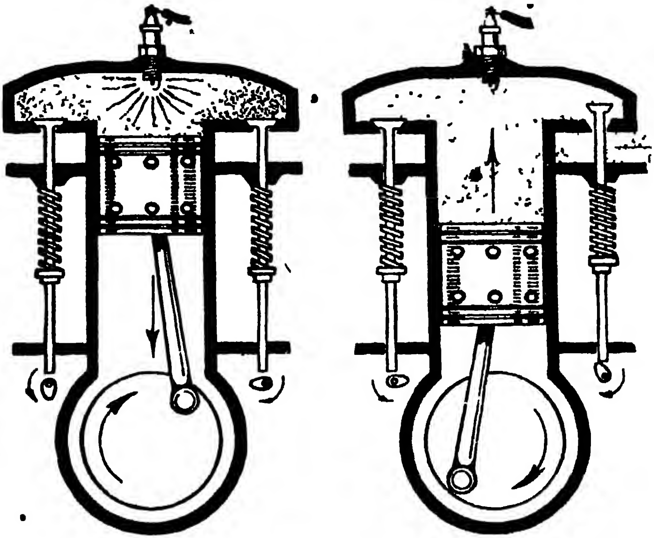


Fig. 102. Fig 103.

Fig. 102. A section of the four-stroke engine during the power stroke
Fig. 103. A section of the four-stroke engine during the exhaust stroke

ent speed and force to make the piston go up and down the cylinder until the next power stroke is performed.

Of course the more petrol vapour and air that is sucked into the cylinder the greater will be the explosion and consequently the power of the stroke and the speed of the machine.

4. ***The exhaust stroke*** (see Fig. 103). At the end of the power stroke the force with which the fly-wheel is travelling carries the piston up the cylinder again whilst the exhaust valve

opens. All the burnt or exhausted gases are pushed out along the exhaust pipe. And now the engine is ready to repeat the four operations.

How the valves are made to open and close

The valves are made to open by the cam-wheels, and to close by their springs. The cam-wheels are made to revolve by a set of cog-wheels which are worked from the crank-shaft on which the flywheels revolve.

The spark

You will read how electricity is sometimes created for motor engines in Book III. The spark, however, is produced on

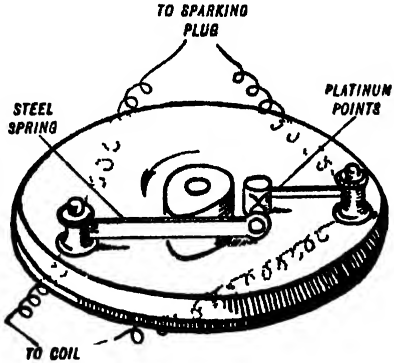


Fig. 104 When the platinum points are made to open by the cam-wheel forcing out the spring then the electric current is completed by an electric spark jumping the points of the sparking plug.

definite occasions (i.e. at the end of the compression stroke) by means of a special switch. This switch, known as a ***contact breaker***, is made to open and close by means of another cam which is also worked from the crank-shaft.

The working of these different cams is timed to take place as required by using various sizes of driving cog-wheels.

The carburettor

Fig. 105 shows how the carburettor works. Petrol from the tank enters at the bottom of the float chamber. From the diagram you will notice that when the float has risen sufficiently high, by reason of more petrol entering the float chamber, then it causes the needle to close the bottom hole and so prevent more petrol entering. As the petrol is used up the float sinks and the needle rises and allows more petrol to enter.

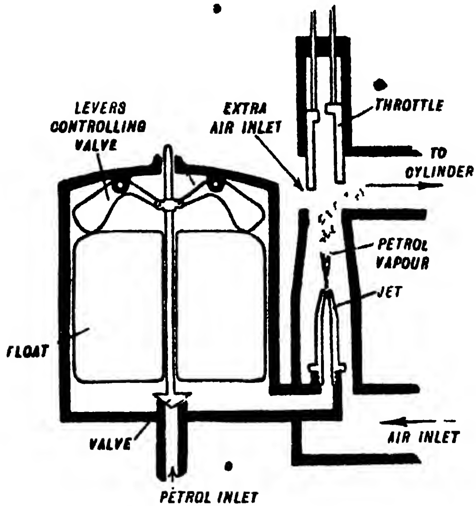


Fig. 105. How the carburettor works.

As the piston of the engine descends during the suction stroke it draws petrol through the fine jet with a sufficient force to turn it into mist of very small drops. This mist of petrol turns to vapour as it mixes with the incoming air.

Internal combustion engines are used to drive motor-cycles, motor-cars, motor-boats, and aeroplanes.

There is a type of internal combustion engine known as the two-stroke engine. It has, however, largely died out in favour of the four-stroke type.

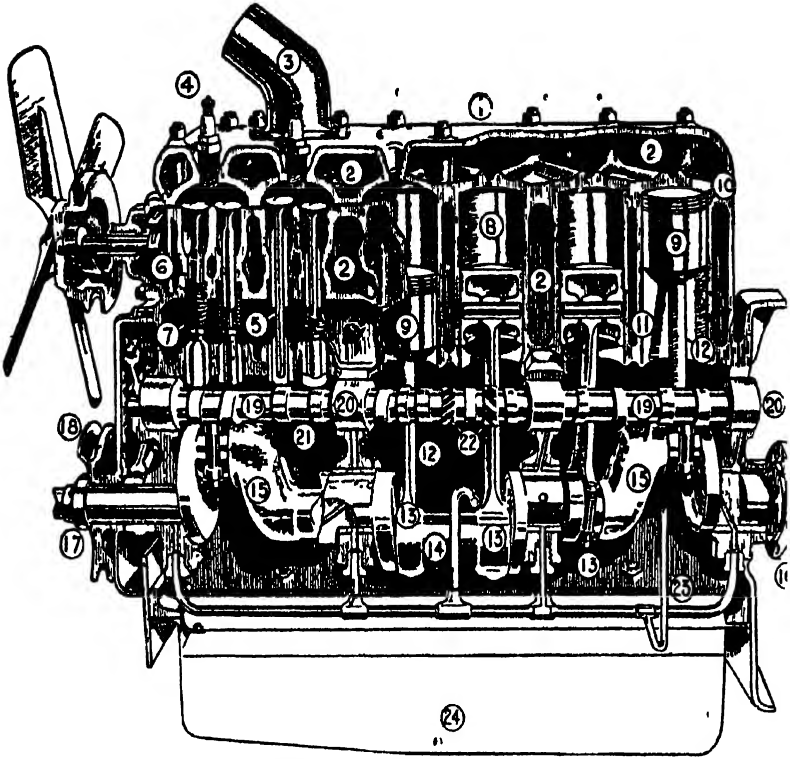


Fig. 106. The interior of a six-cylinder motor-car engine.

1. Cylinder head.
2. Cylinder water space.
3. Water outlet.
4. Sparking plug.
5. Valve.
6. Valve guide
7. Valve spring.
8. Cylinder barrel.
9. Piston.
10. Piston rings.
11. Gudgeon pins.
12. Connecting rod.
13. Big end bearing.
14. Crank-shaft.
15. Crank-shaft webs.
16. Flywheel mounting.
17. Starting-handle dog.
18. Fanbelt pulley.
19. Cam-shaft flange.
20. Cam-shaft bearing.
21. Valve operating.
22. Oil pump and distributor wheels.
23. Oil pump to pressure indicator.
24. Oil sump.

Summary

Whenever an object is moved work is done.

Work = Weight of object × Distance object is moved.

This answer is usually given in foot-pounds Work is made harder by

(*a*) The force of gravity.

(*b*) Friction, i.e. the rubbing of two surfaces, one against the other.

(*c*) Inertia, i.e. powerlessness to move if still or to change speed when moving.

Friction increases with the area and roughness of the rubbing surfaces, and the force holding the two surfaces together. Friction also varies with the nature of material.

Work is made easier by means of

(*a*) ***Levers.*** Such as crowbars, scissors, steelyards, wheel and axles, capstans, winches, wheelbarrows, nutcrackers, and sugar tongs.

The ***mechanical advantage*** of levers

$$= \frac{\text{Distance of power from fulcrum or point of balance}}{\text{Distance of weight from fulcrum}}.$$

(*b*) ***Pulleys.*** Here the mechanical advantage is equal to the number of ropes supporting the movable pulleys.

(*c*) ***The inclined plane.*** The mechanical advantage of an inclined plane is

$$= \frac{\text{Slant height}}{\text{Vertical height}}.$$

(*d*) ***Gears.*** If the gear wheels are without teeth then the mechanical advantage

$$= \frac{\text{Diameter of driving wheel}}{\text{Diameter of driven wheel}}.$$

If the gear wheels possess teeth then the mechanical advantage

$$= \frac{\text{Number of teeth on driving wheel}}{\text{Number of teeth on driven wheel}}.$$

A steam engine is an external combustion engine because the necessary heat has to be produced outside the engine.

Petrol, oil, and gas engines are called internal combustion engines because the necessary burning is produced by an electric spark inside the engine.

The most popular form of internal combustion engine is the four-stroke engine. (A ***stroke*** is a complete movement up or down the cylinder by the piston.) These engines are largely used for motor-cycles, motor-cars, motor-boats and aeroplanes.

The four strokes which make up a complete set of operations that cause this popular engine to run are:

1. The inlet or suction stroke.
2. The compression stroke.
3. The power stroke.
4. The exhaust stroke.

Questions

1. What is meant in science by work?

How much work does a crane perform in lifting half a ton of flour up to a 30 ft. loft?

If an upstairs landing is 12 ft. above the ground floor how much work does a six stone boy do when he climbs upstairs?

2. Mention the ways in which friction (*a*) is an advantage, (*b*) a disadvantage.

3. What is meant by inertia? Illustrate your answer.

4. Show what is meant by mechanical advantage of a lever. Describe two different kinds of levers and mention what is the advantage in using them.

5. Show how pulleys assist us in doing work.

6. How does the inclined plane make work easier?

7. How do we determine the mechanical advantage of gears?

8. Describe how the toy steam engine works.

9. With the aid of a diagram describe how the slide valve controls the steam in a railway locomotive in order that the piston shall be driven to and fro.

10. With the aid of a diagram show how the to and fro movement of the piston turns the wheels of the locomotive.

11. Make a sectional drawing of a four-stroke internal combustion engine and name its parts.

12. Describe the four strokes of the internal combustion engine.

Practical Work

1. The card and coin trick

Place a heavy coin on a thin smooth card and balance it on your forefinger. Flick away the card sharply and you will find that the coin will remain behind.

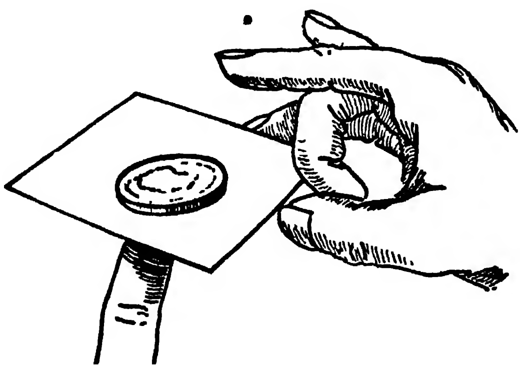


Fig. 107.

2. Catching the coins trick

Arrange the coins as shown. Drop your elbow quickly and catch the coins before they start to move.

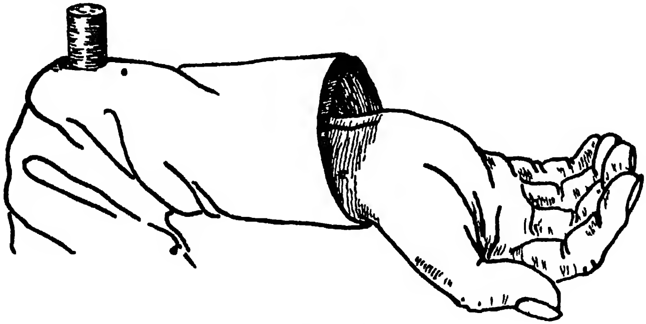


Fig. 108.

3. How to make your own steelyard

Obtain a 3 ft. lath and drill a hole 6 in. from one end to hang the steelyard up. To the short arm fix a weight such as a very small tin filled with solder. Make your balancer from a loop of

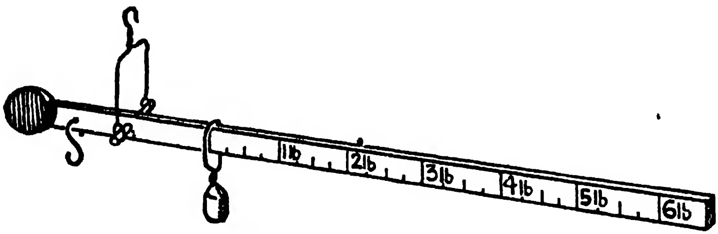


Fig. 109.

copper wire attached to a small weight. About 2 in. from the weight on the short arm fix a hook to carry articles whose weight you wish to determine. Now move the balance along the long arm until the steelyard is horizontal. Mark the position of the balancer as 0. Now hang 1, 2, and 3 lb. weights in turn from the hook, each time moving your balancer until the steelyard is horizontal. Divide the long arm up into lb., ½ lb., ¼ lb., and if possible ounces.

4. Home made scales

To make this model you will need a sewing needle, a knitting needle, corks, medicine bottle, cotton, and two cocoa-tin lids.

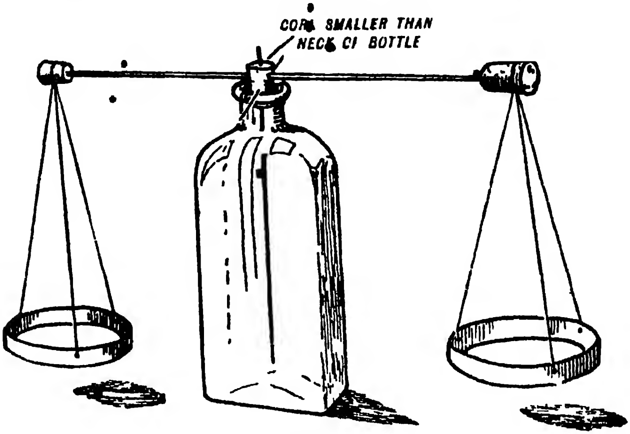


Fig. 110.

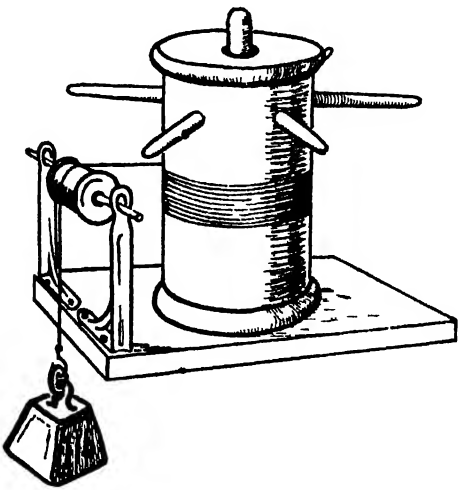


Fig. 111.

5. *A model capstan*

Fix penholders as levers in a large cotton reel. Erect on a base-board as shown.

6. *The determination of friction*

Place a weight (from 1 lb.–7 lb.) on your desk and attach it

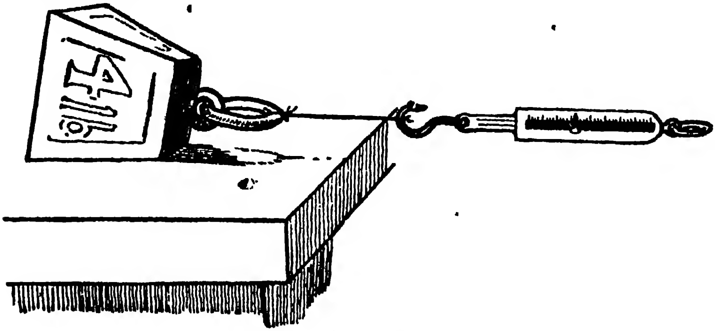


Fig. 112.

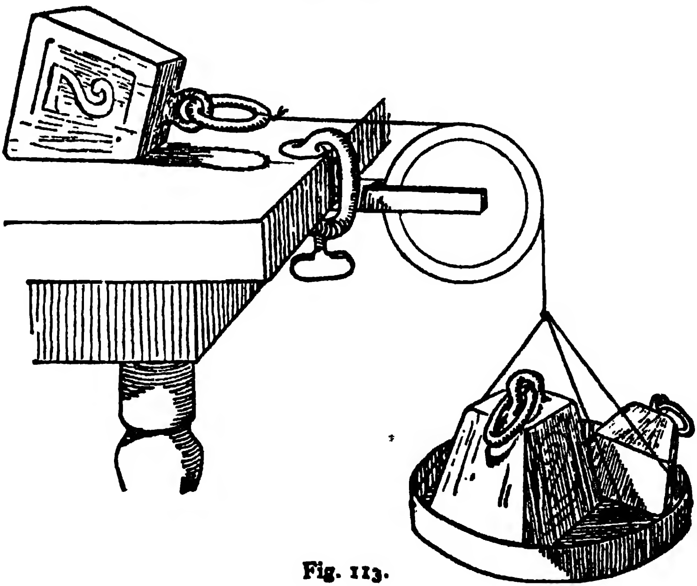


Fig. 113.

to a spring balance. Gently pull the balance horizontally as shown and ***notice the reading when the weight begins to move.***

If you do not possess a spring balance allow the string attached to the weight to pass over a roller arrangement (see Fig. 113). To the free end of the string attach a scale pan similar to that in Fig. 113. And into this place weights until the large weight begins to move.

7. *To determine the mechanical advantages of pulleys*

Pass a piece of string over a pulley as shown (Fig. 114) and

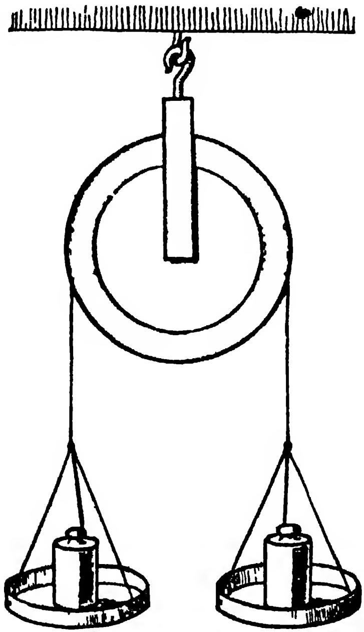


Fig 114.

attach scale pans to the free ends. Put a weight in the left-hand pan and add weights to the other until the left one just begins to ascend.

Repeat the experiment, using two pulleys as arranged in Fig. 87, and again with three pulleys (if this is possible). Enter your results in the table below, and work out the mechanical advantage for the various arrangements of pulleys. N.B. Remember that the "load lifted" must include the weight of the movable pulleys.

No of pulleys used	Load lifted (W)	Wt reqd for lifting W. (P)	Mech Advantage $= \frac{W}{P}$
1			
2			
3			

Fig 115

8. The lever

Drill a hole in the centre of a 3 ft lath and suspend it as shown in Fig. 116. Balance it as nearly as possible by running a balancer

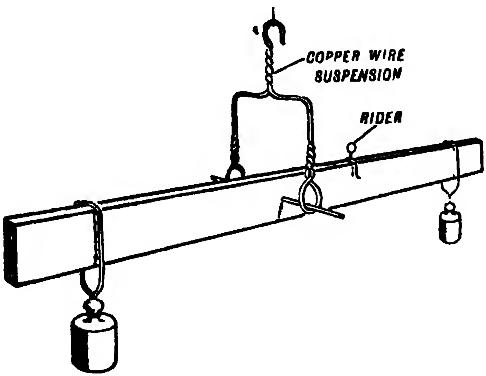


Fig 116

or rider along one arm. Now hang a 100 gm. weight on one side and a 50 gm. weight on the other. Move these weights about until you have obtained the nearest possible balance.

Now measure the distance of each weight from the centre or fulcrum, and enter your results in a table similar to that below.

Wts	Distance of wt from fulcrum (D)	Wt × D
100 gm 50 gm		
100 gm. 25 gm.		
10 gm 50 gm		

Fig 117.

Repeat the experiment using other weights as shown.

9. *How to make a simple steam turbine*

Obtain a "press-in' type of airtight tin as shown in Fig. 118*a*. Make a slight dent in the centre of the lid and punch two small steam-holes at equal distances from the dent as shown. The turbine is made from a cork disc, from $\frac{1}{8}$ to $\frac{3}{4}$ in. thick, cut obliquely along the edge to take the vanes. These are made from cardboard roughly $\frac{1}{2}$ in. × $\frac{3}{4}$ in. according to the size of the tin.

A needle which passes through the centre of the cork acts as a spindle. The point of the needle is held in position by the dent in the lid whilst the upper end is supported by a loop made in the wire soldered on to the side of the tin.

When the water in the tin is boiled the steam comes through the steam-holes and pushes against the vanes thus causing them to rotate.

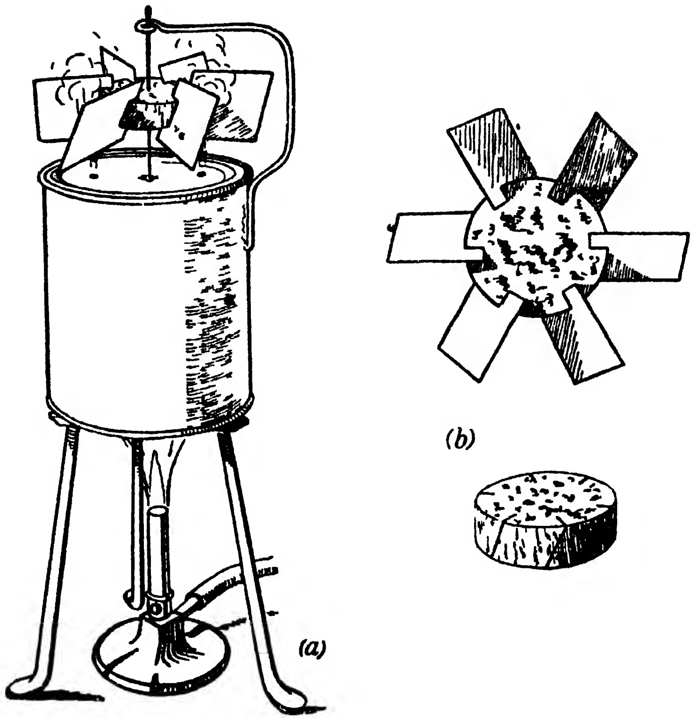


Fig 118 *a b*

SECTION III. BIOLOGY

Chapter 8

THE SOIL

The Formation of Soil

Soil is made up of two things, powdered rock and decayed animal and vegetable matter. The rocks are powdered by the action of water, frost, heat, wind, air and plants (Fig. 119).

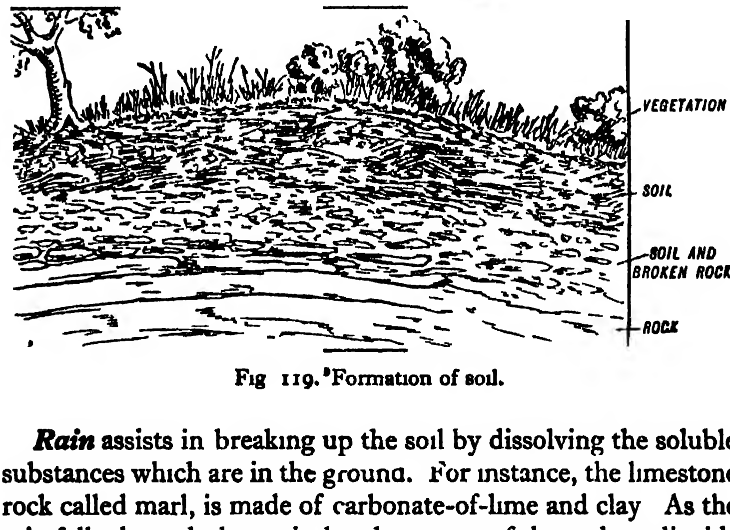


Fig 119. Formation of soil.

Rain assists in breaking up the soil by dissolving the soluble substances which are in the ground. For instance, the limestone rock called marl, is made of carbonate-of-lime and clay As the rain falls through the air it dissolves some of the carbon-dioxide gas contained in the air, forming a weak acid. The carbonate-of-lime easily dissolves in this acid, leaving behind the clay.

Running water, such as that of streams and rivers, wears away the rocks of the river bed or those along the banks. This material is then carried away and deposited elsewhere. The sea, of course, also wears away the rocks round the coast.

Frost also takes a part in breaking up the rocks. During the cold weather, water may collect in the cracks and holes in the rocks. The water then freezes, and as it expands whilst freezing, it makes the cracks larger. Farmers often plough in the autumn, especially if they have clay soil in their fields. (See page 115.) Rain then falls on to the soil. If this water freezes, then the soil may be broken up.

The ***heat*** of the sun causes rocks at the surface to expand. During the night time when the rocks become cool, they contract. This causes them to split and crumble.

Wind does not help to wear away the rocks, but in places where the soil is not covered with vegetation the wind may blow the soil for some distance. The sand storms of the deserts are clouds of sand, which are blown along by the strong winds.

Plants may help to split up rocks. Those plants which grow on the rocks force their roots down through the cracks, making openings into which air and water can pass.

Animals do not help to split up the rocks, but they help in the formation of soil. Animals living in the soil act as underground ploughs, constantly turning over the soil. We learned in Book I how useful Worms are in the soil. Plants will not grow in soil containing no animal or vegetable matter. Animal manure, the dead bodies of animals, and decaying plants all mix with the soil.

Different types of soil

Put a small amount of soil into a jar containing water. Stir this up well and then allow it to settle. Look very carefully at the jar. You will see that the coarse, heavy particles are at the bottom. These are either stones, gravel or ***sand*** particles. On top of this there are the very fine particles of ***clay***. Floating on the top of the water is the animal or vegetable matter which is called ***humus*** (Fig. 120).

Soils are classified according to the amount of sand, clay or humus which they contain. A soil containing a normal amount

of each is called a ***loam***. As the amount of sand increases, the soil is called a ***sandy loam***, or ***sand*** if there is a large proportion of sand. Similarly as the amount of clay increases in proportion to the sand, the soil is called a ***clay loam*** or ***clay***. If the soil contains much humus it is called a ***peaty*** soil.

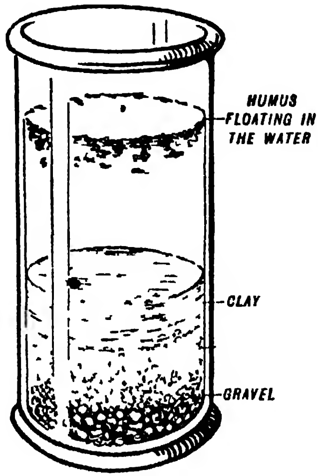


Fig 120. Experiment to show the constituents of soil.

After it has been raining, some soils seem to dry very quickly whilst others remain wet. All soils are porous, as there are small spaces between the particles of soil. This space in the soil is called the ***pore space***. Experiment 5 (p. 149) will show you that the smaller the particles the greater the pore space. In coarse, sandy soils the pore space is about 25 per cent. of the whole soil, but in a clay soil it may be 50 per cent. This pore space should be partly filled with air if plants are to thrive, as roots cannot grow without oxygen. Around each particle of soil there is a film of water. The smaller the particles of soil, the greater the number of films. So there is more water in a fine soil than there is in a coarse soil.

The following experiment shows what kind of soil is able to hold the most water.

Take three filter funnels and put a filter paper in each. Then rest each one on the top of a gas jar (Fig. 121). Put dried sand into the first, dried loam into the second, and powdered, dried clay into the third, taking care that the same amount of each is used. Carefully pour equal quantities of water on to each and see how long it takes for the water to run through the soil.

Sand allows water to run through very quickly, but the water passes very slowly through the clay. A sandy soil is not good for

plants because the water runs through too quickly. The surface soil soon becomes dry, so plants would not have sufficient

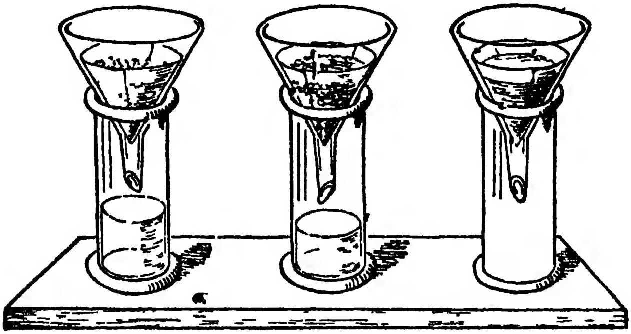


Fig. 121. Experiment to show the water holding capacity of different soils.

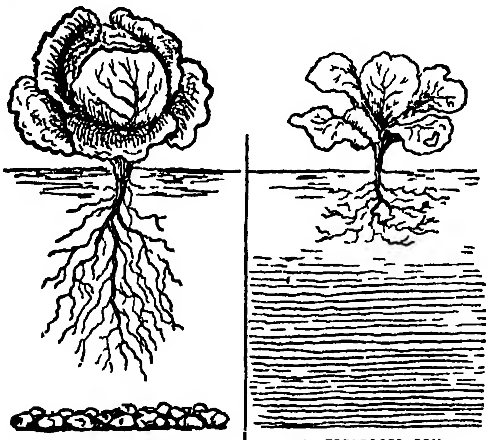


Fig. 122. Diagram showing the effect of a water-logged soil on the growth of a plant.

moisture. A clay soil is also bad for most plants. As the water can only run through slowly, the pore spaces may be filled with water for a considerable time. No oxygen could then get to the roots and the plants would not thrive (Fig. 122). If the pore

space is almost continuously filled with water, as it often is in flat meadows along the banks of streams, the soil is said to be ***water-logged***. A mixture of clay and sand together with humus is the best kind of soil for most plants.

Flocculation

We have learned that clay soil is bad for plants as it only allows water to pass very slowly through it. In some ways farmers have to make this soil useful for plants. They often dig ashes, sand or lime into the soil. The previous experiment tells us why ashes and sand are used. Another simple experiment will show us what action the lime has on the soil.

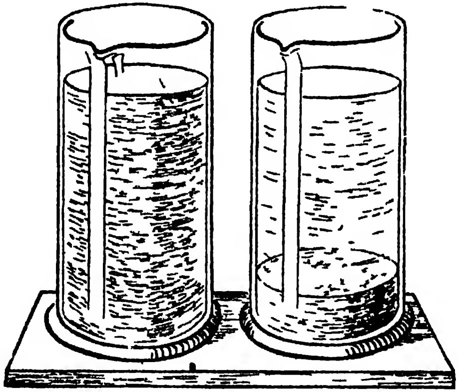


Fig. 123. Diagram to show the action of lime on clay.

Thoroughly mix up some clay and water and pour some of the liquid into two glass jars. Into one of the jars put some powdered lime and leave it for a short time. You will see that the water in the jar containing lime is the first to become clear (Fig. 123). The lime causes the clay particles to stick together forming larger particles. The clay is then said to be ***flocculated***. Water can pass through flocculated clay.

If you put your hand on sand on a very hot day, the sand will be so hot that it will almost burn you. If you put your hand

on clay you will feel that it is not so hot. Sand gets hot very quickly, but it also cools quickly. A well-drained soil, similarly, gets warm fairly quickly. Clay soil on the other hand, is usually wet and so it requires much heat to raise its temperature. Plants do not grow well in a cold soil. A farmer may improve his clay soil by draining it in some way, as well as by mixing ashes, sand or lime with it. Clay soil is slow to warm in the spring time but it cools slowly after the heat of summer has gone. Plants in clay soil are later in growing than those in sandy soil. The latter kind of soil is an "early" soil, whereas the former kind is a "late" soil.

Most soils contain the necessary amounts of salts for plants. Where the plants are growing wild, the salts removed from the soil by the plants are returned to it when they decay. All plants do not use up the same salts from the soil. Some plants require more of certain salts than others, for instance Peas and Beans require different salts from Cabbages. If we grew the same kind of plants on a piece of ground for several years, the soil would soon be without the particular salts that the plants were using. These salts could be added to the soil by putting manure on the ground. A much better way is to grow a crop one year that requires different salts from those used by the crop grown the previous year. In the third year, a crop using yet other salts could be grown. Meanwhile the soil would gradually become richer in the salts which had been used up in previous years. This changing of crops is called the ***rotation of crops***.

Effect of soil conditions on plant growth

We have already learned that the plant is affected by the condition of the soil. The type of plants growing in any place, and the health of the plants, depend on the following things:

1. The type of soil.
2. The amount of water in the soil.
3. The temperature of the soil.
4. The amount and kind of food present in the soil.

Chapter 9

FLOWERING PLANTS

The structure of roots

After having learned many things about flowers, fruits and seeds, we must now study the roots of plants. The root is the first part of the plant to grow out of any seed. If we watch a Bean seed sprouting, we notice that the young root grows downwards for about one and a half inches. From this root, which is called the ***primary root***, side or ***lateral roots*** then begin to grow (Fig. 124).

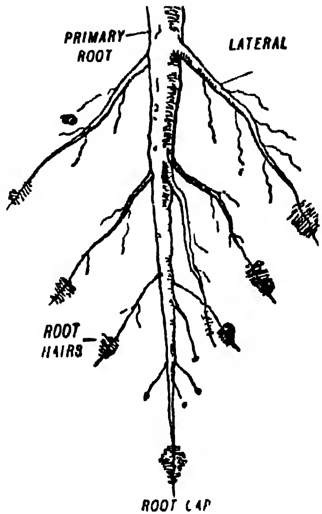


Fig 124. The roots of a plant.

From Book I (p. 99) we found that the growing region of root is immediately behind the tip. This part is very delicate and must be protected from harm while it is pushing its way through the soil, so the growing region is covered with a ***root cap***. Just behind the tip of all roots there are things looking like hairs which are single living cells. These cells, which are called ***root hairs***, are more numerous on roots exposed to moisture than they are on roots in dry soil. The work of the root hairs is to take in water and food. This food consists of salts in solution. The root hairs cling to the particles of soil and can thus make use of the thin film of moisture around them (Fig. 125).

Kinds of roots

Any primary root which grows much larger than its branches is called a ***tap root***. In some plants the tap root is used as a

store-house for food, as it is in the Carrot and Turnip (Fig. 126). When you watched the Maize grain sprouting, you noticed that

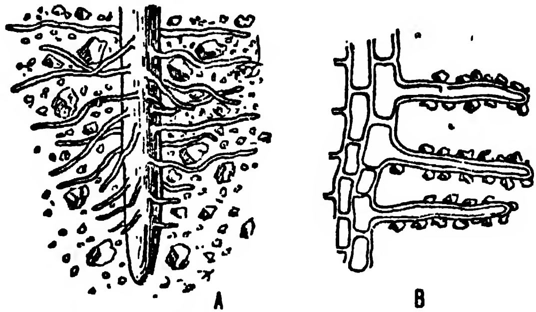


Fig. 125. Root hairs. *A* shows root hairs growing out from behind the tip of a root and penetrating the soil. *B* shows three root hairs more magnified. Each root hair is seen to be one cell. Soil particles are sticking to the root hairs.

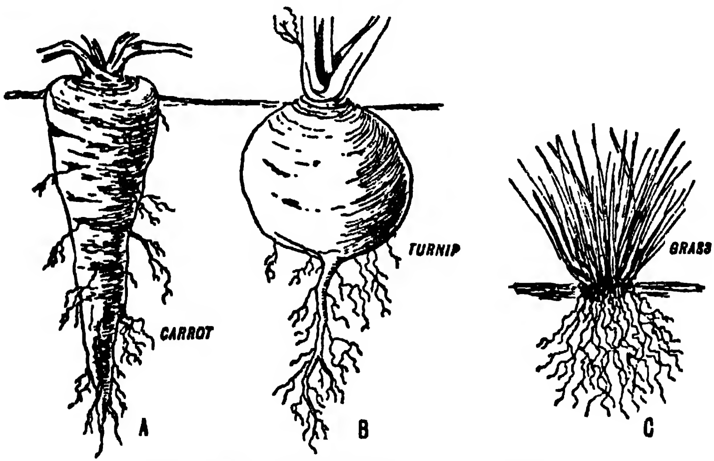


Fig. 126. *A* and *B* are tap roots. *C* is a fibrous root.

other roots, as well as the primary root, grew out of the grain, and these soon equalled the primary root in length (Fig. 127). A plant such as a Grass (Fig. 126 *C*) which has no main root

is said to have a ***fibrous root***. As there is no primary root to anchor the plant in the soil, the fibrous roots are spread out to fix the plant firmly in the ground.

Roots, such as those of the Maize, which do not arise from the primary root are called ***adventitious roots***. These adventitious roots often grow out of stems. For example, roots often come out of the cut ends of stems (Expt. 7, p. 150, chap 9) or out of creeping stems (p. 122) The Banyan trees of tropical forests have strong woody roots growing down from their branches, and these make the undergrowth very dense.

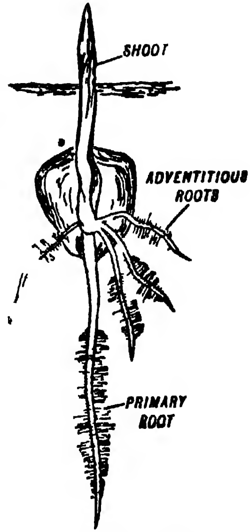


Fig 127. Maize grain showing the primary root and adventitious roots growing out of the grain, which will soon equal the primary root in length

Uses of roots

We have already learned that roots of plants have several functions.

1. They fix the plant firmly to the soil.

2. They obtain water and salts in solution for the plant.

3. Sometimes food is stored in the primary root.

Roots may have special functions The Ivy, for example, has very short roots growing out of its stems These roots cling to any near object, so giving support to the plant. The next time that you see Ivy growing up a tree or up the wall of a house, look for these roots, and try to pull them away from their support.

The stem

After the roots have begun to grow from the seed, the young ***stem*** grows out. From the stem side outgrowths, called ***leaves***, grow, which are different in appearance from the stem. (The structure of a leaf is fully explained in Book III.) A root also has

side outgrowths, but these are always like the root. Because of this it is easy to distinguish roots from stems even though the stem may be underground as in the Buttercup (Fig. 129*B*).

Annuals

The structure of stems depends upon the work they have to do. Some plants, for example the Sweet Pea, germinate from the seed and then in a single year grow into a plant producing flowers and seeds. Such plants are called ***annuals***. In these plants the stems have to grow very quickly to carry the leaves and flowers to the light. The stems also remain green and can do the same work as the leaves. You will learn in Book III what work the leaves do for the plant. It is not necessary for the stems of annuals to be thick, or well protected, as they have few flowers and leaves to bear, and will die before the winter comes.

Biennials and Perennials

All plants are not annuals. The Carrot, Parsnip, Beetroot and Radish, for example, live for two years. During the first year roots and leaves grow and food is stored in the primary root. In the second year the stored food is used as the flowers and seeds grow. Then the plant dies. These plants are called ***biennials***. Plants like trees, that live for more than two years, are called ***perennials***. The stems of perennials have to exist through many winters, so they are protected by a dark, tough and thick covering which is made of cork.

A plant with stems which are soft and short-lived is called a ***herb***. Herbs are usually either annuals or biennials, although sometimes they may live for several years. The Chrysanthemum is an example of a perennial herb. A ***tree*** has a distinct main trunk which bears branches. A ***shrub*** is usually smaller than a tree and has several branches which arise together from one point as in the Elderberry. Trees and shrubs have woody stems and are perennials.

Growth in thickness of stems

As trees and shrubs get older, their stems have to supply the ever-increasing number of leaves with water and salts in solution. These have been taken in by the roots. Also the stem has to bear the weight of more and more branches and leaves. To do this the stems increase in width. The growing and dividing cells which add to the width form part of the greenish layer immediately under the ***bark***. The bark itself is a dead covering of cork which prevents loss of water. As the trunk increases in thickness the bark becomes too small and it splits. New layers

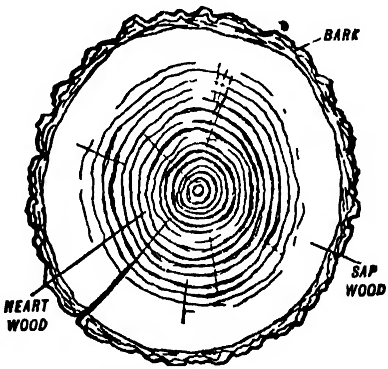


Fig. 128. Transverse section of a branch showing annual rings.

of cork are then formed beneath the old ones. In the Oak and Elm you will see very deep cracks in the bark. Other trees, such as the Plane and Birch, have smooth bark which comes off in flakes.

As the cells underneath the bark divide, those on the inside are changed into cells with hard, thick cell walls which gradually die. These are called ***wood cells***. Water, with the salts in solution, only passes up through those wood cells just inside the bark, which are alive. These cells form the ***sap wood***. As new sap wood is formed, the older sap wood gradually dies forming the central dry mass of dead wood cells, which is called the ***heart***

wood. The heart wood is the chief support or skeleton of the trunk.

The cells of the wood which are formed in the spring are larger than those formed in the autumn when growth is slow owing to the low temperature. So a clear ring of wood is added each year. These rings are called ***annual rings***. They can easily be seen in a section of a tree (Fig. 128). By counting the number of rings you can tell the age of a tree. Some giant trees are 1000 years old.

Knots in wood are sections across the bases of branches which grew out in a certain year. In succeeding years these bases have become enclosed by the growth in thickness of the stem.

Stems with special functions

Normal stems grow above ground but there are some stems which live in the soil and have special functions. In Book I we learned that the normal method of reproduction in flowering plants is by seeds. Some plants, however, use stems for this purpose, and so produce new plants more quickly. There are several types of these underground stems.

1. ***Runners.*** These are really creeping stems, which grow underground in the Buttercup, but above ground in the Strawberry (Fig. 129). Each one has a bud at its tip which can produce a new plant; roots which are adventitious grow out from its base. The creeping stem then dies and the new plant is free.

2. ***Rhizomes.*** Couch Grass (Fig. 130) and Iris have long running underground stems. At intervals along these stems, adventitious roots and leaves arise. The stem is terminated by a bud. Couch Grass is a troublesome weed in the garden as these underground stems often stretch for several feet, and after weeding, the plant will appear again unless every trace of the stem is dug out.

3. ***Tubers.*** The Potatoes which we eat are not roots, as so many people think, but swollen stems, or tubers, where food is stored. The eyes are buds, which, when the tuber is buried in the soil,

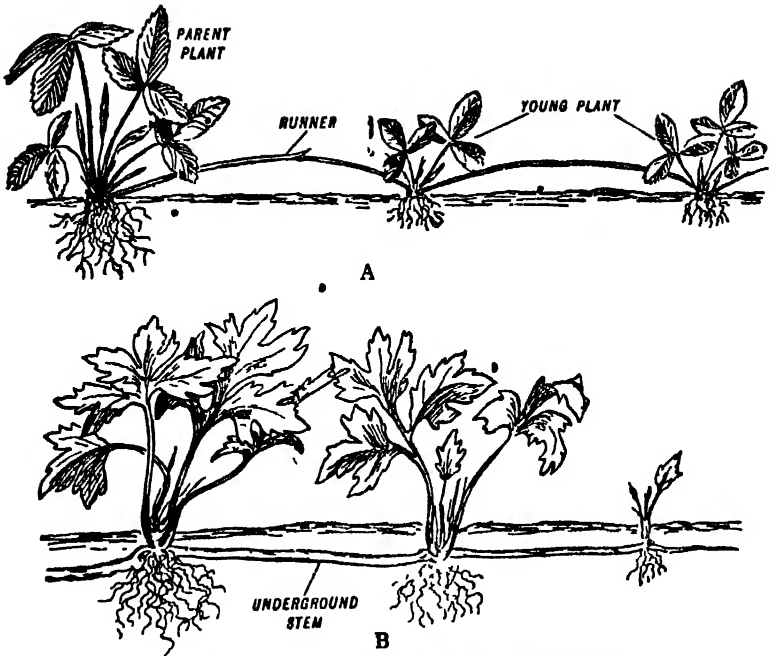


Fig. 129. Runners. *A*, Strawberry. *B*, Buttercup.

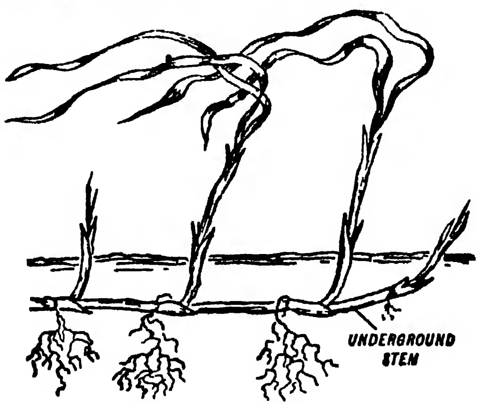


Fig. 130. Rhizome of Couch Grass.

develop into long thin underground stems that bear more tubers (Fig. 131). Adventitious roots also grow from these places on the Potato, but the roots themselves never bear tubers. As the Potatoes are stems, not roots, they will turn green when growing if they are not covered with soil.

4. ***Bulbs.*** If you cut an Onion in two lengthwise you will see its structure (Fig 132) At the base of the bulb there is a small

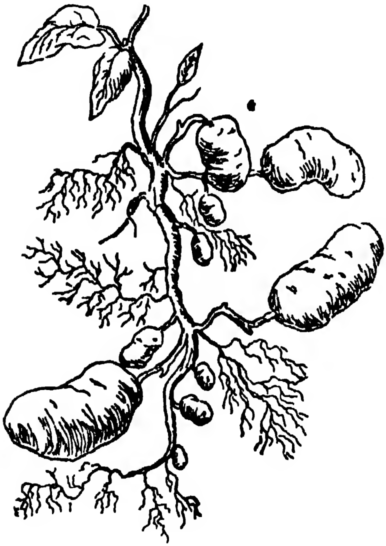


Fig 131 Tubers of Potato plant

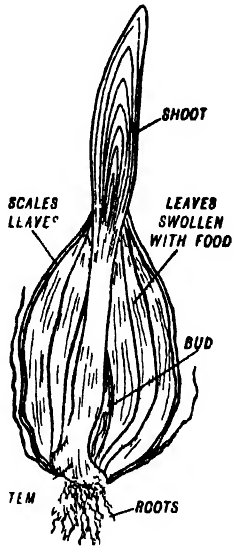


Fig 132 Bulb cut in two

pointed stem from the under side of which roots arise. The remainder of the bulb consists of leaves which are swollen with food. These leaves are protected on the outside by other scale-like leaves. The way in which these leaves are arranged may be compared with the arrangement of leaves in an ordinary bud. A bulb is really a large bud, whose leaves are swollen with food. A new bulb arises as a small bud on the short stem at the base of one of the fleshy leaves (Fig. 132).

Climbing stems

The stems of some plants are too weak to support the weight of the leaves and flowers, so they climb up any plant or obstacle near them. When we grow Kidney Beans or Hops we always

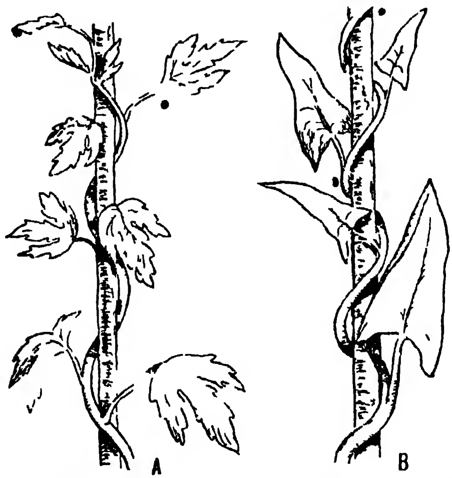


Fig. 133 Climbers. *A*, Hop twining in same direction as the clock. *B*, Convolvulus turning in the opposite direction

put sticks near the young plants, up which they may climb. The stems twine themselves round these supports. The stems of the Hop and Honeysuckle revolve in a clockwise manner, whereas those of the Kidney Bean and Convolvulus go round in the opposite direction (Fig. 133).

Chapter 10

ANIMALS WITH BACKBONES

All animals with backbones belong to one of five classes: 1, Fishes; 2, Amphibians; 3, Reptiles; 4, Birds; 5, Mammals.

Fishes

These animals are clearly adapted for life in water. If we look at a Goldfish swimming, for example, we see that the cylindrical body which is covered with scales, and the pointed head and tail, allow the fish to swim without any difficulty. In fact the

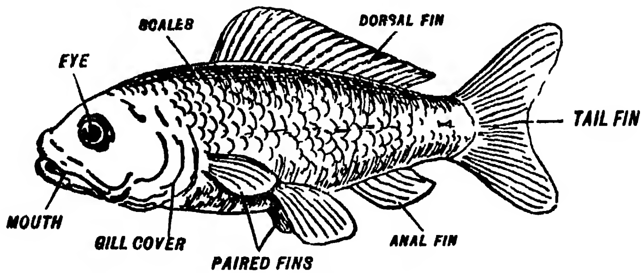


Fig. 134. The Goldfish.

body is ***stream-lined***. Inside the animal there is an ***air bladder*** which makes the fish have the same specific gravity (see Book I) as the water, and so it needs to make no effort to keep up in the water.

Fishes have ***fins*** for swimming (Fig. 134). If you look at a Goldfish you will see that it has two pairs of fins which correspond to our arms and legs, and three simple fins, the tail fin, the dorsal fin on its back and the anal fin near to the anus.

Fishes have ***gills*** for breathing instead of lungs like we have. Blood containing carbon-dioxide is sent by the heart to the gills. Here carbon-dioxide passes out in solution into the water, and

dissolved oxygen is taken in from the water into the blood, in which it circulates to all parts of the body. The gills are protected on each side of the body by a ***gill cover***. If you lift up the gill cover of a Herring you will be able to see the structure of the gills. The spaces between the gills, called ***gill slits***, open from the mouth to the space under the gill cover. When a fish opens its mouth to breathe, water enters the mouth and at the same time the gill cover is closed. Then the mouth is shut, driving the water through the gill slits and past the gills, while the gill cover opens as the water is forced out.

I expect you have all heard of, or eaten, "hard" and "soft" roe of fishes. The "hard" roe is a mass of small eggs which the female lays in the water. The "soft" roe is a mass of sperms (see Book I) which the male sheds on top of these eggs, when they have been laid, to fertilise them. Most fishes do not protect their eggs after they have been laid. Instead, they lay a large number of eggs. Then in spite of the dangers that surround the young fishes, it is probable that at least a few of the many young will survive until they are fully grown.

Some fishes, however, do protect their eggs. The small fishes with spikes on their backs found in ponds and streams which are called Sticklebacks build nests of weeds. The male builds the nest. When eggs have been laid in the nest by several females and fertilised by the male, he keeps guard over the nest, fiercely driving away intruders.

The Salmon

Both the Salmon and Eel are interesting because they pass part of their lives in fresh and part in salt water.

The largest Salmon are from 4 to 5 feet long. They are found on both sides of the North Atlantic and the North Pacific Oceans. When large Salmon, which are living in the sea, are ready to lay their eggs, or ***spawn***, they travel inland up the rivers, often jumping up waterfalls or weirs. The eggs are laid in rivers during the months of September to January. When the young

fish are about two years old, they travel down to the sea, where they feed and grow rapidly. One or two years afterwards they return to the river to spawn.

The Eel

Eels living in the streams and rivers of all countries of Europe go down to the sea to breed. They travel to the depths of the Atlantic Ocean near the West Indies. Here they spawn, but never return again. The young Eels come back to the European rivers, taking about three years to do so, having travelled at the surface of the sea.

Flat fishes

Plaice, Soles and Turbot are peculiar fishes living in the sea. If you look closely at them you will see that they are lying, and

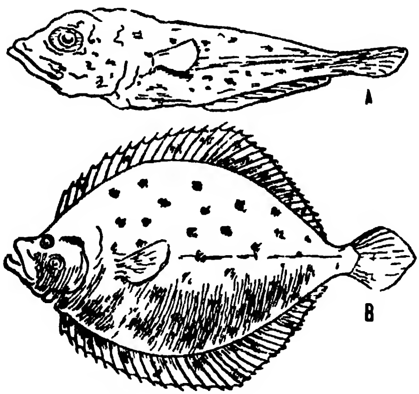


Fig. 135. Flat fish *A*, young stage which looks and swims like an ordinary fish. *B*, adult stage [drawn to smaller scale] Both drawings are of the left side of the fish.

they swim, on one side of their bodies. The gill openings are one on the upper, and one on the lower surface. The mouth is placed as it would be if the fish swam like other fishes, but the skull is twisted, so that both eyes are on the upper side (Fig. 135).

These Fishes start life swimming as other Fishes do, but later they turn on one side, while the skull gradually twists. They can change their colour and pattern to match the ground on which they are lying.

Amphibians.

Frogs, Toads and Newts belong to this group. They all start life as water animals and then change into land animals. Most

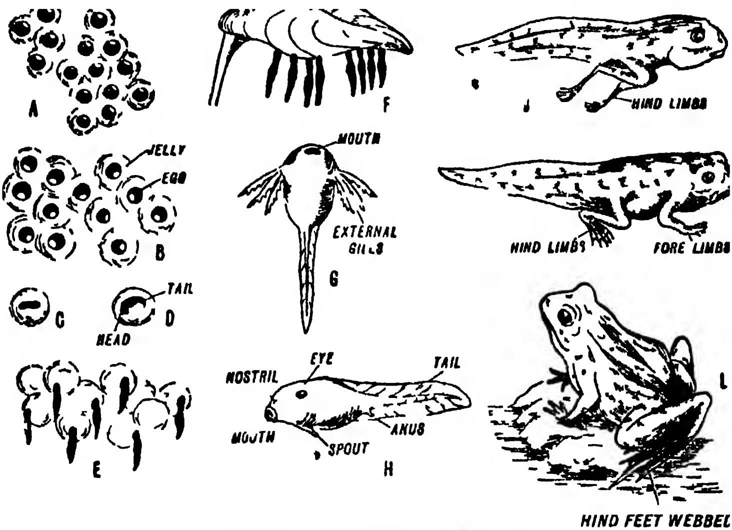


Fig 136. Life history of a Frog.

of you, I expect, have watched Frogs gradually develop out of the eggs. During the early spring you will find ***Frog spawn*** in most ponds, ditches and canals. The spawn consists of a number of eggs. Each egg is surrounded by clear jelly which swells when laid by the frog in the water (Fig. 136 *A* and *B*) If you get some Frog spawn and put it into an aquarium or a glass jar containing water and water weeds, you can watch the eggs gradually growing and changing into Frogs (Fig. 136).

Life history of the Frog

Several days after they have been laid, the black eggs change their shape (Fig. 136 *C* and *D*), until after about 14 days a tiny creature emerges out of the jelly (Fig. 136 *E*). This small animal has no mouth, no eyes, no gills and no limbs, but only a ***sucker*** with which it fastens itself to a leaf (Fig. 136 *F*). It is fed by the food, or yolk, which still remains inside it from the egg. A ***mouth*** soon develops in front of the sucker. The small animals, or ***Tadpoles*** as they are called, breathe by means of gills, called ***external gills*** because they grow outside the body (Fig. 136 *G*). Through the gills oxygen dissolved in the water is taken into the blood and carbon dioxide is passed out in solution into the water. As the Tadpole increases in size four ***gill slits*** appear on each side of the neck, and ***internal gills*** are formed like those in Fishes, while the external gills shrivel. A fold of skin forms a gill cover over the internal gills, and the Tadpole then breathes like a Fish (Fig. 136 *H*). Water goes into the mouth, passes over the gills, and is then forced out through one opening called the ***spout*** (Fig. 136 *H*). When the Tadpole is fully grown the ***back legs*** appear, and several days later the ***front legs*** appear, one emerging through the spout. ***Lungs*** develop while the gills wither and the tail shortens and then the young Frog comes out of the water on to the land (Fig. 136 *L*).

At first Tadpoles live on plants, but as they turn into Frogs they eat small Insects. Fully-grown Frogs eat Insects, Worms or Slugs.

The tongue of a Frog is peculiar, as it is joined to the front and not the back of the mouth. The Frog can throw its tongue forward, and then the tip reaches a long way beyond the mouth. This is useful when the Frog is catching Insects with its tongue.

Tadpoles are readily eaten by many animals in ponds, and Birds and Snakes eat small Frogs. So Frogs, like most Fishes, lay many eggs, so that at least a few of the young survive.

Frogs have a naked skin, that is the skin is not covered with

scales, feathers, or hair. Our skin is covered by an outer layer of dead skin. This is not so in Frogs. The outside of their skin is made up of living cells, so they are able to breathe through their skin as well as through their lungs. If their skin becomes dry, the cells die and they can no longer breathe through their skin, so they die. Frogs can be compared in this respect with Earthworms (Book I).

During the winter, when the temperature is low, Frogs ***hibernate***, that is they hide themselves in holes in the ground where it is damp. Here they remain, almost lifeless, until the springtime.

Toads

Toads can be distinguished from Frogs by their shape and their skin which is more wrinkled and warty and less moist Their eggs are laid in strings of jelly, which are fastened round water weeds Each string of jelly contains 20 or 30 eggs.

Newts

Compare the life history of a Newt (Fig 137) with that of a Frog. The eggs are very difficult to find They are laid singly on

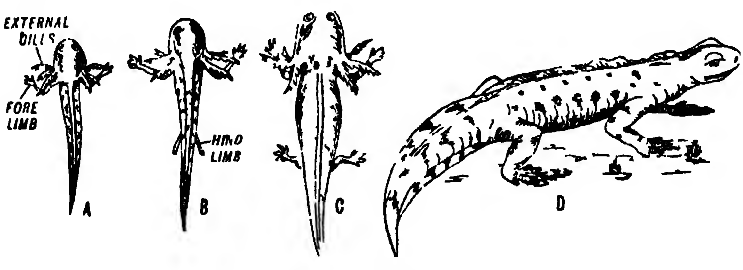


Fig 137 Life history of a Newt *A*, *B* and *C* are stages in development. N B the fore limbs appear before the hind limbs *D*, adult

leaves of water plants, the edges of which are carefully folded over. If you are fishing in a pond or ditch you may see young

Newts amongst the weeds. At first you may think that they are small Fishes, but on looking closer you will see the external gills and tiny limbs (Fig. 137 *A*, *B* and *C*). The limbs develop very early in life, and the young Newt keeps its external gills for a long time. Unlike the Frog, the fully-grown Newt does not lose its tail. During the breeding season the male Newt has a crest along the middle of its back.

Reptiles

Snakes, Lizards, Crocodiles and Tortoises belong to this group. The skin is covered by horny scales in Lizards and Snakes, and by an armour of thick scales in Crocodiles and Tortoises. Most Reptiles hatch out of hard-shelled eggs, the young ones being similar in appearance to their parents. The eggs of the Adder hatch before they are laid, so the young ones are born alive. There are between five and six thousand kinds of Reptiles in the world to-day. As they prefer a sunny climate, only six kinds are found in Britain, three sorts of Snakes and three kinds of Lizards.

Snakes

Many Snakes have a bite which is poisonous. Small channels connected with poison glands are found in the front teeth or

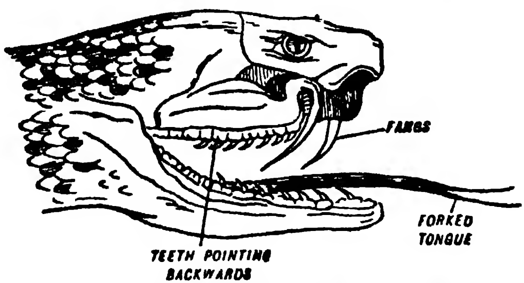


Fig. 138. The head of a poisonous Snake.

"fangs" (Fig. 138). The two halves of the lower jaw are not firmly fixed together in front as ours are, but are joined by a substance

which can stretch like elastic. This allows the Snake to swallow prey larger than it could otherwise do.

The ***Adder*** or ***Viper*** is the only poisonous Snake found in Britain and it feeds on Frogs and other small animals. The harmless ***Grass Snake*** feeds on Frogs and Fishes, and can sometimes be seen swimming about in water. The colour of the Grass Snake varies. Some are almost black, but usually they are a grey-green colour. The underparts are black, and behind the head, which is also black, there is a yellow collar. The Adder does not have a yellow collar behind its head. It is usually a dark-reddish brown colour, and along its back is a line of black blotches joined together to form a zig-zag pattern. Near the head this line ends, and on the head itself there is a V-shaped mark

The three British ***Lizards*** are all about six inches long but are different in colour. They feed on Snails, Worms and Insects.

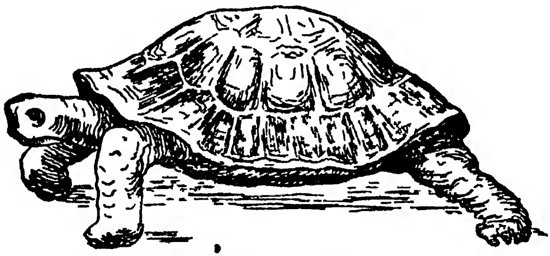


Fig. 139. Tortoise.

Crocodiles and ***Alligators*** have long bodies and tails covered with thick scales. Their legs are short, the tails being used for swimming. They can lie in the water, showing only their eyes and nostrils. These animals will eat Fish, but if they are hungry they seize any animal that comes near them, whether it is large or small. The female lays her eggs on the bank, then she covers them up with soil and leaves them to hatch in the sun.

Tortoises like most other Reptiles are found in the hotter countries of the world. The body of a Tortoise is covered with a peculiar case (Fig. 139). ***Turtles*** differ from tortoises in having paddle-like limbs. They live chiefly in the water, but in the

breeding season the female comes to land to lay her eggs. Most of these animals are vegetarians. The best tortoiseshell is obtained from a certain kind of Turtle.

To-day Mammals are the most abundant large animals in the world. Many ages ago, long before there were any Men on the earth, this was not so. Most of the larger animals were then Reptiles, but they were different from the Reptiles alive to-day. Some of them were very large animals. In the Natural History Museum, London, the skeletons of many of these Reptiles can be seen. We know that these Reptiles existed because remains of their bones, teeth and scales have been found in the rocks. Such remains are called ***fossils.***

Birds

Birds are found in all parts of the world. The structure of Birds is specialised in many ways to enable them to fly. I expect all of you when you have had a Turkey, Fowl or some other Bird for dinner have noticed that the breast bone has a ridge or ***keel*** down the middle of it. To this bone the wing muscles, used in flight, are attached. Birds like the Ostrich, which are running Birds and do not fly, have no keel bone. You have, no doubt, also noticed how light Birds' bones are. Many of them are hollow, and the larger ones are porous. Birds can actually pass air into their bones from their lungs, so making their skeleton lighter.

Much strenuous work has to be done by the muscles of Birds when in flight, so a lot of energy is needed. Heat and other sorts of energy are produced in animals by the chemical combination of their food with oxygen which they breathe in. As Birds require so much energy when flying, their lungs are comparatively larger than ours. In addition a number of thin-walled air-sacs, which are prolonged into several of the bones, are connected with the lungs, and serve as storehouses for air which is passed into them from the lungs. The Birds can use this air when it is needed.

Birds are covered with ***feathers,*** which like the hairs of Mammals are produced by cells in the skin. Between the feathers

(or hairs in Mammals) and the skin there is a layer of air Air, as you know, is a bad conductor of heat, and the layer of air kept

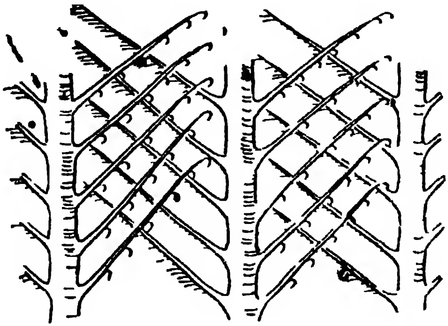


Fig 140 Part of feather magnified, showing barbs and barbules

Fig 141 Wings *A*, the Bat's wing is a skin supported by arm, second to fifth fingers, and leg *B*, the feathers of the Bird's wing are on the arm and enlarged second finger

by feathers therefore prevents loss of heat from the body. Each of the large or ***quill*** feathers has a central quill. On either side of the quill there are ***barbs*** each of which has numerous branches called ***barbules*** (Fig 140) The barbules on one side of each barb have hooks on them, which interlock with the

barbules of the next barb. This gives greater resistance to the air as the Bird is flying, in just the same way that we get resistance to the water when swimming by keeping our fingers together.

Fig 141 shows the structure of the wing of a Bird, and also of a Bat (a Mammal) which, you will see, is constructed in quite a different way. We all know what a variety of colours there is in the feathers of Birds, especially in those of Birds living in hotter climates The feathers or ***plumage*** of the male Birds are often more brilliantly coloured than those of the female, for example the Peacock and Peahen.

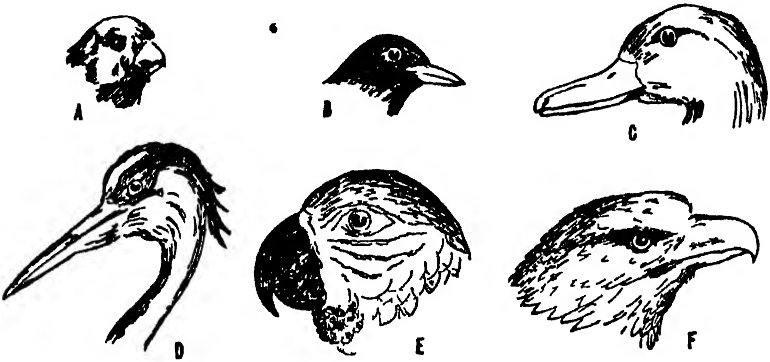


Fig 142 Types of beaks *A*, Sparrow short, strong beak for eating seeds *B*, Blackbird slightly longer beak for catching and eating Worms and Insects *C*, Duck broad flat beak for straining small creatures from the mud *D*, Heron long beak for catching Fish *E*, Parrot strong, hooked beak for holding and cracking nuts *F*, Eagle strong, sharp, hooked beak for catching and tearing prey to pieces

The skull of a Bird ends in a hard ***beak***. The beaks of Birds vary in shape, as they are adapted to catch or eat the particular food that the Bird requires In Fig. 142 a few different types of beaks are shown

The feet of Birds are also interesting, as they too, tell us the habits of the Birds (Fig. 143).

All Birds lay eggs These vary in size, shape and colour.

Birds which nest in holes lay white eggs, whilst eggs that are laid in the open are coloured and so are not easily seen.

The majority of Birds build nests in which to lay and hatch out their eggs, though a few like the Cuckoo use the nests of other Birds. Nests vary considerably in their shape, construction and material. There is not sufficient space here to describe the many different kinds of nests, but if you look carefully you will

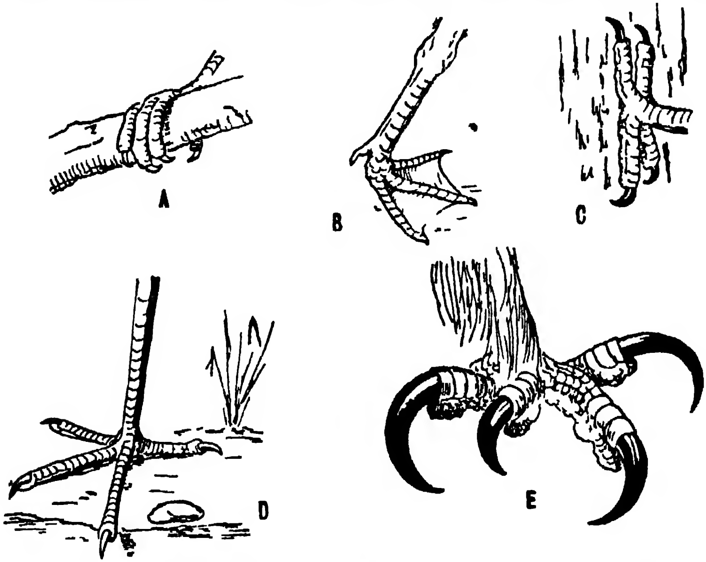


Fig. 143 Types of feet. *A*, Dove: adapted for perching with three toes pointing forward and one backward *B*, Duck: webbed foot for swimming *C*, Woodpecker: climbing Bird with two toes pointing forward and two backward *D*, Heron: the spreading toes which prevent the wading bird from sinking in the mud. *E*, Eagle: the sharp curved talons of the Bird of prey

be able to find out for yourself what materials are used. For instance a Rook makes a very coarse nest of large twigs; a Robin makes a very soft nest chiefly of moss and feathers; a Thrush makes its nest of small twigs and grass, and lines it with mud which it carefully smooths out with its breast. It is also interesting to find out in how many different places nests are found.

Just a few examples can be given here Nests are found in trees (Rooks), bushes (Thrushes), on the ground (Skylark), in hollow trees (Woodpecker), under the eaves of houses (Sparrows), in holes in the ground (Sand Martin), and on the cliffs (Seagulls)

The mother bird, sometimes assisted by the father, sits on the eggs for a time until they hatch out Some young Birds are able to run about and feed themselves shortly after they come out of the eggs Chickens, Partridges, Grouse and Pheasants are able to do this Young Thrushes and Sparrows, however, are very feeble when they hatch out These young Birds are fed by their parents until they are able to seek their own food

Migration

During the late summer or early autumn many Birds fly to other countries We say that these Birds ***migrate*** The Swallow,

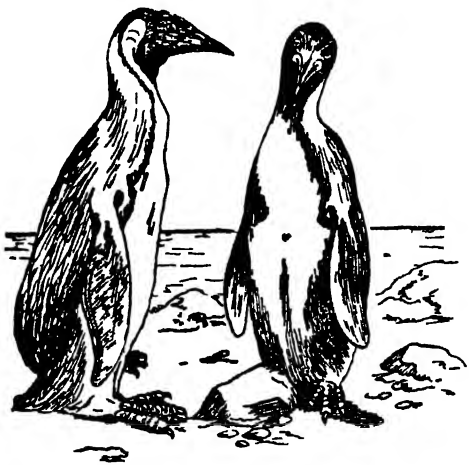


Fig 144 Penguins

Swift, Cuckoo and many other Birds fly from our country to hotter climates Most of them go to various parts of Africa Other Birds, such as the Snow-bunting and Redwing come to

Britain in the autumn from the colder countries near the Arctic Circle.

Birds can be put into two classes. Most Birds are called ***Flying Birds*** because they can fly. The Penguin (Fig. 144) belongs to this class although it can no longer fly but uses its wings for swimming. A few Birds, such as the Ostrich, cannot fly and so are called ***Flightless Birds***. These Birds can run away very quickly if threatened by any danger. Ostriches are so strong that they are often used to draw carriages in which one person can sit.

Mammals

This group of animals includes the largest animals living to-day. Man is a Mammal and so are Dogs, Rabbits, Horses, Elephants and even Whales. The name Mammal is given to the class because the females produce milk to feed their young. All Mammals breathe air, by means of lungs, throughout their life. The most obvious difference between Mammals and the other groups of backboned animals is that they have hair on their bodies. Mammals and Birds are called "warm-blooded" animals. Reptiles, Amphibians, Fishes and all backboneless animals are called "cold-blooded". These terms are not really true. "Warm-blooded" animals are really able to regulate the temperature of the body, so that it remains constant whether the temperature of the outer world is hot or cold. "Cold-blooded" animals have no such control, and their temperature varies with that of the outside world.

In Book III we shall carefully study the structure of the Human Body. As Man is a Mammal, we need not deal here with the structure of a Mammal's body.

There are a number of groups of Mammals.

1. Pouched Mammals

The most familiar example of this group is the ***Kangaroo***. The young ones are sheltered, for some time after they are

born, in a pouch formed by a fold of skin on the underside of the mother's body (Fig. 145).

Fig 145 Rock Wallaby.

2. *Whales*

Although ***Whales*** live in the sea and look like Fishes, they are Mammals (Fig 146) Their bodies are not covered with scales, and they have lungs and breathe air. Their tails are flattened horizontally instead of vertically like those of Fishes, and help in the continual journeying to the surface of the water to breathe Although these animals live in cold water, their bodies are kept warm by the layer of fat, called ***blubber***, which is under the skin Whales up to ninety feet long have been caught They are the largest animals living. Elephants are the largest animals on land, and Giraffes are the tallest.

Whales can be divided into two groups. ***Toothed Whales*** including the ***Porpoises*** and ***Dolphins*** which feed on Fishes,

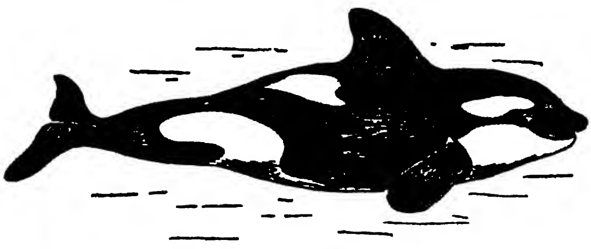


Fig. 146. Killer Whale

and ***Whalebone Whales*** which have no teeth even when they are fully grown. Instead they have hundreds of strips of whale-

bone forming a sieve in their mouth. Water, which is taken in with each mouthful of food, can be drained off and passed out of the sides of the mouth, whilst the minute creatures, which the Whale eats, are kept in the mouth, and then swallowed.

3. *Hoofed Mammals*

These animals are so called because each toe is protected by a horny covering known as a ***hoof***. The number of toes varies in the different animals. The ***Horse***, for example, has only one toe and so is said to be "odd-toed". Other animals have two or four toes and so are "even-toed". There are generally four toes, but two may not reach the ground, and appear as two horny lumps. The ***Cow, Goat*** and ***Sheep*** have two toes, the ***Pig*** and ***Hippopotamus*** have four toes (Fig. 147).

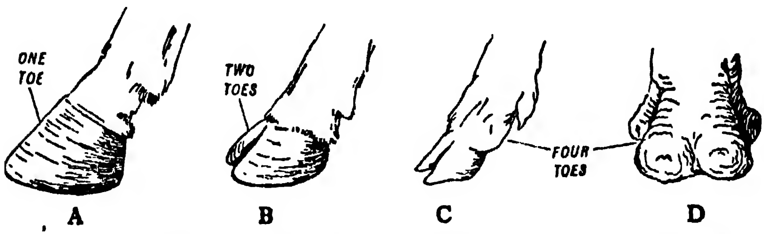


Fig. 147. Hoofed animals. *A*, Horse. *B*, Cow. *C*, Pig. *D*, Hippopotamus.

Pigs will eat flesh as well as vegetable foods. All other animals belonging to this group are ***herbivorous***, that is they eat only plant food. ***Deer, Oxen, Giraffes, Camels***, Sheep and Goats chew the cud. These animals have a very peculiar stomach (Fig. 148). Grass or other plants are quickly cropped by these animals, and swallowed. The food goes into the first part of the stomach, and remains there until the animal finds a nice quiet place where it can lie down and chew its meal at leisure. Sodden food is then passed back in small quantities from the first part of the stomach into the mouth again, where it is well chewed, ground by the teeth, and mixed with a juice called ***saliva***,

produced in the mouth. The food is then swallowed a second time and passed into the second part of the stomach, where it is strained. It then goes into the third part of the stomach where digestion continues.

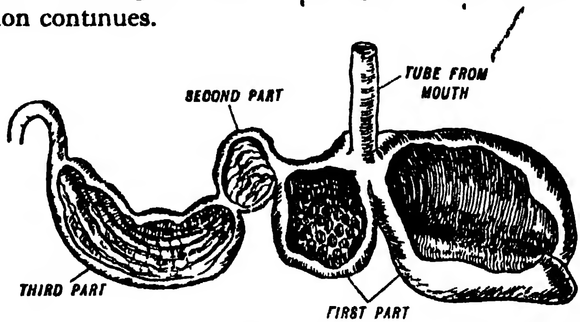


Fig 148 Cow's stomach.

4. *Elephants*

Elephants are the largest land animals living to-day. Although an Elephant is so large, it can walk along making very little noise, as it has padded soles on its feet. Elephants are peculiar in having ***tusks***, which are very long teeth, and also a ***trunk*** which is a drawn out snout. The Elephant uses its trunk for a variety of purposes —for putting food into its mouth, rooting up plants, feeling its way in the dark, and sucking up water for spraying over its body or for drinking. Elephants are herbivorous.

There are two kinds of Elephants—the African Elephant and the Indian Elephant. The Indian Elephant can be distinguished from its African cousin by its larger head and smaller ears and tusks. This Elephant can easily be taught to do useful work for Man. The African Elephant is very difficult to tame, and is valued more for its ivory than for its usefulness.

5. *Beasts of Prey*

All those Mammals which prey on or kill other animals for their food, are included here. These flesh-eating animals are said to be ***carnivorous***. They all have sharp claws on their

limbs. Animals similar to the ***Cats, Lions*** and ***Tigers***, are able to hide their claws inside their feet when walking or running (Fig. 149). This enables them to move about silently, and the claws are also kept sharp. ***Dogs, Wolves, Foxes*** and ***Jackals*** cannot withdraw their claws into their feet, so the claws become blunt and cannot be used for catching prey. These animals run down their prey using only their teeth for killing.

Fig 149 Cat's feet *A*, showing claws *B*, claws hidden

Carnivorous animals always have large, strong and pointed side or ***canine*** teeth which are used for catching prey. They also have sharp pointed back teeth which are used for tearing food to pieces

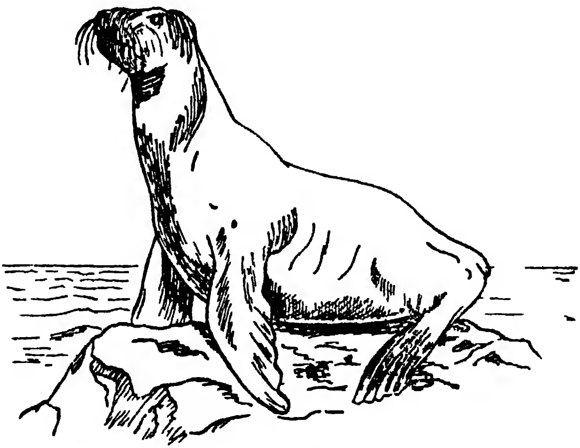


Fig 150 The Sea-lion Limbs adapted for swimming

A Cat has a rough tongue with which it can remove flesh from bones. A Dog has a smooth tongue, and so has to bite the meat with its teeth.

Weasels are very useful beasts of prey as they prevent the countryside from being overrun by Rabbits, which they kill.

Bears also belong to this group. The white Polar Bears live chiefly on Fish. The Brown Bears are not entirely carnivorous as they will eat fruit, berries, and other plant food and are very fond of honey.

Sea-Lions and ***Walruses*** live in the sea, their food consisting of Fish Their front and hind limbs are peculiarly shaped, and can be used for swimming, as well as for "waddling" along the ground (Fig 150) ***Seals*** can only use their hind legs for swimming as they are joined to the tail. The baby Seals are helpless when they are born, but they soon learn to swim

6. Gnawing Mammals

This is a large group of fairly small Mammals, which are chiefly vegetarians They have many enemies, and cannot protect themselves very well, but they are found in large numbers because they breed very quickly ***Rabbits, Hares, Rats, Mice*** and ***Squirrels*** belong to this group. They have front teeth which grow continuously throughout their life, as they are always being worn away by constant nibbling of food

Rabbits make burrows in the ground, but the Hare never burrows. Young Rabbits are very helpless when born, and have only a very sparse covering of hairs. The mother puts them into a nest which she makes with hair off her own body

A Squirrel can climb trees and has a bushy tail It hibernates.

Mice and Rats are pests to Man. Certain Rats which are sometimes brought to our docks, carry the germs of plague Circular discs are put on the ropes of ships in dock, to prevent Rats entering by running up the ropes.

7. Insect-eaters

Hedgehogs, Moles and ***Shrews*** belong to this group of Mammals, which is another large group of small animals. Although they are called Insect-eaters, these Mammals will eat

other things as well, such as Mice, Snails, Worms and Slugs. Hedgehogs are also fond of eggs. Moles eat Earthworms which they find in the soil where they live. The Hedgehog hibernates, living on the fat which is stored in its body.

8. Bats

Bats are very similar to the Insect-eating Mammals, but they are put into a group by themselves because they can fly. Each wing is made of skin which stretches between the four very long fingers of the hand, and the side of the body. The thumb alone is not part of the wing, and ends in a hook-like nail. When asleep, Bats hang downwards by the claws of their feet (Fig. 151). They sleep in a dark corner during the day. Bats have very poor sight, but the skin on the face is very sensitive to the movement of the air, so that they can avoid obstacles even when flying in darkness.

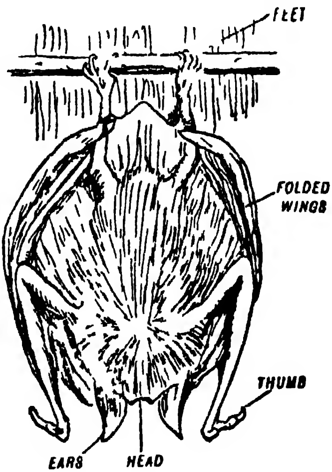


Fig 151 A Bat asleep.

9. Men, Apes and Monkeys are called Primates

All these animals have a fairly large brain, so their heads are different in shape to other Mammals. Their eyes are at the front of the head, and not at the side. Except for ***Man***, these animals are adapted for climbing trees, and their feet as well as their hands, can be used for grasping The Man-like Apes, such as the ***Gorilla, Orang-utan*** and ***Chimpanzee*** can walk on their hind limbs as we do. The Monkeys of America possess tails with which they can grasp, and these are useful when they are climbing. These animals are mostly vegetarian.

Questions

When possible, carefully labelled diagrams should be given to illustrate the answers.

Chapter 8

1. How does sand differ from clay? Illustrate your answer by describing any experiments that you know.

2. If there was too much clay in your garden soil, how could you improve it?

3. When a soil is water-logged, how can a farmer make it fit for growing crops?

4. After it has been raining, why do you see puddles on some soils and not on others?

5. What is meant by loam? Is this a good kind of soil for plants? Give reasons.

6. How does water help in the formation of soil?

7. Write a short essay on how soil is formed.

8. Why is lime added to a clay soil? Illustrate your answer with an experiment.

9. Why is it not advisable to grow the same crop on a piece of land for several successive years?

10. What conditions of the soil affect the growth of plants?

11. Why are both sand and clay bad soils in which to grow plants? What is the best kind of soil for plants?

Chapter 9

1. Plants usually reproduce by means of seeds. In what other ways can plants reproduce?

2. Why do annuals have slender green stems and perennials thick, brown stems?

3. How can you tell the age of a tree? What is your reason for saying so?

4. On which part of a root do the root hairs grow? Of what use are the root hairs?

5. Why is the root tip covered with a cap?

6. What is the difference between a tap root and a fibrous root? Of what use is each kind of root to the plant?

7. What is an adventitious root? Give three examples of adventitious roots.

8. What are the uses of (*a*) roots, (*b*) stems?

9. What is (*a*) an annual, (*b*) a biennial, (*c*) a perennial? Give examples of each kind of plant.

10. How does a stem increase in thickness? Why is there a difference between the wood formed in the spring and that formed in the autumn?

11. What is (*a*) sap wood, (*b*) heart wood? Of what use to the plant is each kind of wood?

12. How is a knot in wood formed?

13. Describe the life of a Carrot from the time the seed is set until the plant dies.

CHAPTER 10

1. Name three Fishes that you could catch in a river, and three in the sea. What two Fishes live in both fresh and salt water?

2. How does a Fish breathe?

3. Compare the life histories of the Eel and the Salmon.

4. What is peculiar about a Flat Fish?

5. Why do many Fishes lay a large number of eggs?

6. How do (*a*) Sticklebacks, (*b*) Newts protect their eggs?

7. What are the chief differences between the development of a Frog and that of a Newt?

8. Write a short essay on English Snakes.

9. Why is the bite of most Snakes poisonous?

10. How can a Snake swallow its prey whole, even when the prey is bigger than its mouth?

11. Where do Crocodiles live? Why are they dangerous animals?

12. Of what use is a Bird's beak? By means of drawings describe three different kinds of beaks and say what its particular use is.

13. How can Birds keep a store of oxygen?

14. Write a short essay on Birds' nests saying where nests can be found, and what materials are used in making nests. Describe the nests of any two Birds.

15. What are the chief differences between Reptiles, Birds and Mammals?

16. How is a Bird adapted to flying?

17. Compare and contrast a Bat and a Bird.

18. What is the difference between Whalebone Whales and Toothed Whales? Of what value to us are Whales?

19. What do we mean by a "warm-blooded" animal? What groups of animals are warm-blooded?

20. Name any animals that hibernate. Why do they hibernate?

21. What is a Mammal? Name one animal in each group of Mammals mentioned in this book and say why you put it in the group.

22. Write a short description of a Bat.

23. What animals are called Beasts of Prey? Why are they so called?

24. Compare and contrast Rabbits and Hares. How are the young protected?

25. Find out all you can about a Hedgehog, and write a short description of it.

26. What are the chief differences between an Indian and an African Elephant? Of what use is each kind of Elephant to Man?

27. How could you explain that a Whale is a Mammal and not a Fish?

Practical Work

Labelled diagrams should be given whenever possible.

Chapter 8

1. Put equal quantities of clay and sand into two jars of water and stir. Which settles first and why?

2. Germinate seeds in clay, sand and humus, and note the results.

3. Test various soils for their water-retaining capacity (see p. 113).

4. Grow seeds in water-logged soil and well-drained soil. Note results. (Two flower-pots one with and one without a hole can be used.)

5. To find the pore space of soil.

Put a known quantity of soil into a measuring jar and add a known quantity of water. Note the reading. Subtract the reading from the sum of the quantities of soil + water to get the pore space.

Quantity of soil = +
Quantity of water =
Total = -
Reading =
Pore space =

6. Make lists of the names of all plants found on several different patches of ground in different places. At the same time find out what kind of soil is there and compare your results.

7. Write down the names of any plants that you find in water-logged soil.

8. Experiment to find the amount of humus in soil.

Take a weighed amount of dried soil and put it in a tin over a flame. Heat it strongly for 15 mins. Allow to cool then weigh the soil again. The difference in weight is the weight of the humus.

Chapter 9

1. Strip off the bark of a branch of a tree to see the green layer between the bark and the wood

2. If you see the stump of a tree, find out how old the tree was by counting the annual rings.

3. Make carefully labelled drawings of (*a*) a Potato, (*b*) a rhizome.

4. Cut a bulb in two and draw it, showing all the parts mentioned in the text

5. Make lists of all the plants that you can find with underground stems. Head your lists (*a*) Runners, (*b*) Rhizomes, (*c*) Tubers, (*d*) Bulbs.

6. Set Carrot or Parsnip seeds and watch them grow. Compare the tap root after the first year's growth, and after the second year. What has happened to the tap root and why?

7. Put Willow or Poplar cuttings in water. Watch the growth of adventitious roots.

8. Collect stems of different ages and compare them.

9. Make a collection of the bark of trees, and name your specimens.

10. Find as many climbing plants as you can, and say how they climb.

11. Germinate Pea or Bean seeds and draw the roots at different stages to show the parts of roots.

12. Examine the roots of plants in gardens. Make drawings and describe the following roots: Carrot, Turnip, Wheat, Cabbage, Lettuce, Pea and Grass.

13. Experiment to show that plants will only take in substances in solution.

Take two jars filled with water. To one add red ink, and to the other powdered carmine which will not dissolve in the water. Place a small plant in each with its roots dipping in the liquid. Leave for several days, then cut the roots above the surface of the liquid. Why is one coloured and not the other? Which one is coloured?

14. Examine the plants in your garden with woody stems. Are they annuals or do they live throughout the winter?

Chapter 10

1. Draw a Herring to show all the external parts mentioned in this book. Lift up the gill cover to see the gills.

2. Watch a Fish swimming. Notice the movement of the fins, and the opening and closing of the mouth and gill covers when breathing.

3. Examine a Plaice or a Sole and notice the peculiar shape of its head.

4. Get some Frog spawn and keep it in an aquarium. Draw the different stages and note the date when each stage is reached.

[It is useful to keep preserved specimens of different stages. This can be done by putting specimens into formalin.]

5. When the Tadpoles are nearly fully grown, before their legs appear, feed them on meat. If small pieces of meat are

tied with cotton, they can be suspended in the water for a short time and then removed. You will see the Tadpoles clinging to the meat, and eating it.

6. Examine the tongue of a Frog. It is fastened at the front end of its mouth and not at the back as our tongue is.

7. Make a collection of Birds' eggs and nests, and name your specimens. [Eggs should not be taken out of nests unless they have been forsaken by the parent Birds, or one egg can be taken out of a nest containing several eggs. Nests should not be collected until after the breeding season.]

8. Make a list of the Birds you see that (*a*) hop, (*b*) walk.

9. Write down the names of all the Birds you see in summer and in winter.

10. Examine the paws of a Dog and a Cat. How do they differ? Why?

11. Look closely at any Hoofed Animals you can and say whether they are odd-toed or even-toed.

12. If it is possible, look at a Cow's stomach to see the structure. [Cows' stomachs are difficult to obtain as they are sold as "tripe" which can be eaten.]

13. Draw a feather. Look at it under a microscope or lens to see the barbules.

14. Collect pictures of Animals with Backbones, and put them into the groups mentioned in this book.

15. It is very difficult and in some cases impossible to study the animals mentioned in this book in their natural surroundings. Several animals can be kept in captivity with little trouble. These may be caught, or bought from a live-stock dealer. Visits could be paid to zoological gardens.

16. Visit any museums that are near to see specimens of animals.

Appendix A

QUESTIONS REQUIRING SHORT ANSWERS

These are intended for periodic test purposes. In the majority of cases the answers should not occupy more than one line.

Chapter 1

1. From where do all the various kinds of heat come?
2. How does the heat we obtain from coal come from the sun?
3. What is friction?
4. Mention two methods of obtaining heat by friction.
5. What is tinder?
6. How can you make tinder?
7. What are the contents of a tinder box?
8. What is the name of the substance largely used in match heads, before the safety matches were invented?
9. What is the difference between these matches and safety matches?
10. How is it that the burning glass can produce heat?
11. How do we know materials are wasted when coal is burnt away in a fireplace?
12. Who was the first known person to make coal gas?
13. State briefly how coal gas can be made.
14. Name some of the by-products obtained in the manufacture of coal gas.
15. Why is the Bunsen burner so called?
16. What do you do to change a bright luminous sooty gas flame into a hot non-sooty flame?
17. What is the cause of backfiring?
18. What is it that gives off the heat in a gas fire?

19. Coal gas is a dangerous substance. Give two reasons for this.

20. Mention anything else you know about coal gas.

Chapter 2

1. How does heat travel through a solid?

2. Name three substances through which heat will rapidly pass.

3 Name six substances through which heat can only pass slowly.

4. Give one reason which shows that the earth is a poor or non-conductor of heat.

5 What other name do we give to non-conductors?

6 How do the metal cooling fins on an air-cooled motor-cycle engine cool the engine?

7. How does heat travel through liquids and gases?

8. What happens to both liquids and gases when they are heated?

9. Draw a diagram showing how a land breeze is formed

10 Draw a diagram showing how a sash window will ventilate a room.

11. How does the heat of the sun pass through space and reach the earth?

12 From what other bodies does heat travel by this method?

13. Why is it impossible for the sun's heat to reach the earth by conduction or convection?

14 How can you tell that the light and heat from the sun travel at the same enormous speed (186,400 miles per second)?

15. Give one reason why heat is considered to be a form of energy

16. When aeronauts make ascents in daytime they go nearer to the sun. Why, then, do they become colder?

17. What colour of material is coolest to wear in summer?

18. Why is this?

19. What could you do to a house in summer time so that the rooms would be cooler?

20. Make a rough sketch of a vacuum flask and name the parts.

21. Give three reasons why the vacuum flask is able to keep hot things hot and cold things cold for long periods.

Chapter 3

1. What is the meaning of "expansion"?

2. What is the opposite of expansion?

3. How are substances made to expand?

4. What happens to substances when they expand?

5. What are the brothers Montgolfier noted for?

6. Why should kettles and saucepans not be filled too full?

7. Why are gaps left between lengths of railway line?

8. When telegraph wires are erected in summer they are left sagging slightly. Why is this?

9. Why do thick glass vessels crack when hot water is put into them?

10. Why are rivets, for holding boiler plates together, put in whilst hot?

11. What is the cause of burst water pipes in winter?

12. How can you show that some solid substances expand more than others?

13. What causes a pendulum clock to lose time?

14. Make a rough diagram of a compensated pendulum and name the parts.

Chapter 4

1. What do we mean by temperature?

2. What is a thermometer?

3. How do we get the word "thermometer"?

4. What are the freezing point and boiling point on a Fahrenheit thermometer?

5. How did this thermometer get its name?

6. What are the freezing point and boiling point on a Centigrade thermometer?

7. What is the meaning of Centigrade?

8. For what purposes are the two thermometers used?

9. What is the name of the thermometer that the doctor uses to take his patient's temperature?

10. What is the temperature of a person in good health?

11. A clinical thermometer should not be washed in hot water. Why?

12. Make a rough diagram of a metal thermometer.

Chapter 5

1. What is the chief difference between solids, liquids, and gases?

2. What is the meaning of the expression "latent heat"?

3. The temperature of boiling water cannot be raised. If you go on heating the boiling water what will the additional heat do?

4. Why is a scald from steam worse than one from boiling water?

5. Why does petrol feel cold to the hand?

6. Why is it easy to catch a chill after you have been perspiring?

7. How would you prevent a chill of this sort?

8. When the surface of a hot liquid is blown the liquid cools more rapidly. Why is this?

9. What is the effect of rain in (*a*) summer, (*b*) winter?

10. Why do thaws have a cold effect?

11. What is fog?

12. What is the cause of hailstones?

13. How is the snowflake made?

14. What is sleet?

15. What does an hygrometer tell you?

16. What is the name of the place where weather recording instruments are kept?

17. What kind of weather may be expected if the barometer reading is more than 30 in.?

18. What kind of weather may be expected if the barometer reading is between 29 in. and 30 in.?

19. What do you know if the wet and dry bulb thermometer readings are practically the same?

20. What kind of weather is cyclonic weather?

21. What kind of weather do we have during an anticyclone which occurs in winter?

22. What kind of weather do we have during an anticyclone which occurs in summer?

23. What is the name of the instrument which is used for obtaining the speed of winds?

Chapter 6

1. What do we mean in science by work?

2. How much work does a bricklayer do in lifting twenty 1 lb. bricks to the roof of a house 20 ft. above the ground?

3. What do we mean by the force of gravity?

4. What is friction?

5. Give a reason for aeroplanes being more speedy than motor-cars.

6. How can the friction between two bodies be increased?

7. How can friction be decreased?

8. What is inertia?

9. When a tramcar or 'bus comes to a standstill which way do the passengers lurch—forwards or backwards?

10. Why is this?

11. What is meant by "fulcrum"?

12. How can you increase the power of a lever?

13. Write down the names of four well-known types of levers.

14. Make a rough sketch of a pair of scissors and mark the place where it is easiest to cut material.

15. What is meant by "mechanical advantage"?

16. What is the mechanical advantage of a 40 ft. ladder placed against a house which is 20 ft. high?

17. What is the pitch of a screw?

18. What is the thread of a screw?

19. What is the mechanical advantage of the toothed wheels (sprocket wheels) of a bicycle?

Chapter 7

1. Write down another word for generated.

2. Give the meaning of internal.

3. What is an internal combustion engine?

4. Give another name for the steam engine.

5. What do we mean by the strokes of an engine?

6. Write down the names of the four strokes of a motor-car engine.

7. What is the name of the wheels which, when they turn, cause the valves to open?

8. Make a drawing of one of these wheels.

9. Say how you would start engines in the following machines: motor-cycles, motor-cars, and aeroplanes

10. What is the name of the instrument through which petrol enters an engine?

CHAPTER 8

1. Why are boulders along the banks of rivers, or by the sea-shore, rounded?

2. What is meant by the "pore space" of soil?

3. What is peat? What use can we make of it?

4. Name the three chief constituents of soil.

5. What is meant by the "Rotation of Crops"?

6. What agents help to break up rocks to form soil?

CHAPTER 9

1. Of what use are the "eyes" of a Potato?

2. Why is the outer skin of a perennial tough?

3. What is the use of the runners of the Strawberry plant?

4. Why does the bark of trees crack or peel off?

5. How can you tell a tree from a shrub?

6. What are annual rings?

7. What colour is a Potato that has not been covered with earth? Why?

Chapter 10

1. What is peculiar about a Flat Fish?

2. A Frog's skin must always be moist. Why is this so?

3. How can you tell a Frog from a Toad?

4. Why are there few Reptiles in England?

5. Name three Birds that cannot fly. How do they get away from their enemies?

6. Why is there a keel on the breast bone of a Bird?

7. What Bird never makes a nest of its own?

8. What is meant by (*a*) Migration, (*b*) Hibernation?

9. How does a Kangaroo protect its young?

10. How do Rabbits warn one another that danger is near?

11. Although many Rabbits are killed by Man and other animals, yet there are still many Rabbits to be found in the country. Why is this so?

12. Why are Mice and Rats called pests?

13. From what animal do we obtain the best tortoiseshell?

14. Bats are seen flying about at dusk, and not during the daytime. How do they avoid hitting objects when flying?

15. How do we know that animals were living in the world many eras before Man existed?

Appendix B

SUGGESTIONS TO TEACHERS AND PUPILS ON GENERAL PROCEDURE

1. The pupils should read certain portions from the book as indicated by the teacher. During this time the teacher will be free to continue preparing apparatus either for demonstration purposes or individual experimental work.

2. Then a short space of time, e.g. ten minutes, should be allowed for general discussion between teacher and pupils By extending the time it would be best to give demonstration experiments during this period.

It is particularly important that the time allowed for the science lesson should be fairly apportioned in accordance with the demands of the syllabus. This should prevent certain items being stressed at the expense of others.

3. (*a*) No. 2 should be followed, where possible, by individual experimental work.

There is no necessity for the teacher to prepare instruction cards. Sufficient instructions are given at the end of each section of the book.

(*b*) The pupil should record at least the results of his experimental work. It is a good plan to make him write up his work under the following headings:

(i) What I did.
(ii) What happened.
(iii) Why these things happened.

This will give good training in logic and English, and will justify reasonable time being allotted, in the School Time-table, to science.

4. The summary should be copied by the pupils into their note books and learned, and set questions should be answered.

In spite of the demands of the many other subjects in the school curriculum it is strongly recommended that during every week at least one hour is spent over items 1, 2 and 3; and half an hour over item 4, and the answering of the questions appearing in Appendix A.

All work done by the pupils should be recorded. Records of individual experimental work and of the answers given to the questions appearing in Appendix A will be of particular value. If pupils show a good knowledge of the answers to these last-mentioned questions the teacher may rest assured that really valuable work has been done.

In order to avoid confusion over apparatus and the number of experiments performed, it has been found to be a good practice if the experimental work of the pupils is recorded in a manner similar to that indicated in the following copy of a specimen page from a teacher's record book.

Name of Pupil	Title of experiment						
	The Siphon	Testing for hardness of water	Softening water	Splitting up water	Water pressure		
Hall, Reg.	9.7						
Price, Thos.		9.7					
Smith, Robt.			9.7				

N.B. The figures in the columns after the names represent the day and month that the experiment was commenced.

Appendix C

APPARATUS AND MATERIALS NECESSARY

The following is a list of all the material required for the second-year course. The dimensions and general particulars issued are of those pieces of apparatus which it will be most suitable to use.

Items specially marked (printed in italics) are not essential, but if purchased through any surplus in the school allowances or through a school fund they will be found to give added stimulus to the work.

All the prices* accompanying the apparatus specified have been taken from the catalogue of Philip Harris and Co., Ltd., Birmingham. They are amongst the foremost scientific instrument makers and suppliers in the country, and we are indebted to them for the loan of blocks, and courteous assistance in the examination and choice of suitable apparatus. Customers will find them most willing to give advice in connection with the problems of science apparatus.

1 lb. assorted soft glass tubing. Diam. 3-16 mm.	1*s*. 6*d*. lb.
1 spring balance in ounces to 8 lb.	8*s*. 6*d*. each.
½ gross assorted corks.	7*s*. 6*d*. gross.
2 tripods.	1*s*. 3*d*. each.
2 retort stands, with bosses.	5*s*. each.
2 Bunsen burners.	1*s*. 3*d*. each.
1 lb. mercury.	5*s*.–7*s*. 6*d*. a lb.
4 iron wire gauze 4 in. squares.	2*d*. each.
2 pairs crucible tongs.	5*d*. each.
1 iron wire gauze 30 cm.	1*s*. each.
1 magnifier (9787 recommended).	2*s*. 6*d*. each.
1 compound bar (copper and iron or brass and iron).	2*s*. 6*d*. each.
1 set bell-shape brass weights, ¼ oz. to 4 oz.	7*s*. 3*d*.

* Prices are subject to revision.

1 set ring-shape iron weights, ½ lb. to 7 lb.	10*s*. 1*d*.
1 box metric weights, 1 gm. to 100 gm.	7*s*. 6*d*.
4 single pulleys, aluminium cast.	1*s*. 3*d*. each.
2 pulley blocks, each of three sheaves.	2*s*. 9*d*. each.
1 electric bell.	2*s*. 6*d*.
1 metre rule (graduated cm. and in.).	2*s*.
½ metric rules (graduated cm. and in.).	1*s*. 3*d*. each.
1 rain gauge, complete.	10*s*. each.
1 maximum and minimum thermometer (Six's)	8*s*. each.
1 wet and dry bulb hygrometer (Mason's).	10*s*. each.
2 Centigrade thermometers	2*s*. 3*d*. each.
2 Fahrenheit thermometers.	2*s*. 3*d*. each.
1 clinical thermometer (magnified scale).	2*s*. 6*d*. each.
1 pneumatic trough. Diam. 25 cm., ht. 10 cm.	3*s*. 3*d*. each.
2 flasks. 375 c.c.	8*d*. each.
2 glass beakers. 375 c.c.	9*d*. each.
6 test tubes (combustion glass). 6 in. × 1 in.	5¼*d*. each.
5 ft. india-rubber tubing (black). Interior diam 5 mm.	3*d*. each ft.
4 ft. india-rubber tubing (black). Interior diam. 3 mm.	2*d*. each ft.
1 *Davy safety lamp.*	12*s*.
1 *boiler and engine mounted on a substantial wooden base together with a dynamo connected to a lamp. The engine will drive the dynamo which will produce sufficient electricity to light the lamp. This is specially recommended as it can be used again later in the electricity course.*	£7. 7*s*. 0*d*.
3 gas jars. Diam. 5 cm., ht. 20 cm.	1*s*. 1*d*. each.
3 filtering funnels. Diam. 9 cm.	10*d*. each.
1 measuring jar. 200 c c	1*s*. 10*d*. each.
1 packet filter papers. 12·5 cm.	1*s*. per 100.

Chemicals

4 oz. ether.	2*d*. oz.
4 oz. glycerine.	2*d*. oz.
½ lb. lampblack.	1*s*. lb
1 oz. mercuric iodide.	1*s*. 9*d*. oz.
1 oz. phosphorus red.	6*d*. oz.
1 oz. phosphorus yellow.	10*d*. oz.
1 lb. potassium chlorate.	9*d*. lb.
1 lb. potassium nitrate (saltpetre).	10*d*. lb.
¼ lb. potassium permanganate.	1*s*. lb.
4 oz. shellac varnish.	1½*d*. oz.
½ lb. sulphur (flowers).	5*d*. lb.
2 lb. sulphuric acid (technical).	3*d*. lb.
1 lb. formaldehyde (44 per cent.).	1*s*. 2*d*. lb.

Dealers in specimens of livestock

Specimens can usually be obtained from any local livestock dealer.

Names of dealers are given in the journal of the "School Nature Study Union". This is issued to non-members for 1*s*. and can be obtained from the Secretary, 45 Cheviot Road, West Norwood, London, S.E. 27.

Appendix D

Some Useful Reference Books

SIDEBOTHAM, H. *Wild Animals.*
Shown to the Children Series:
SCOTT, M. K. C. *Birds.*
BLAIKIE, A. H. *Nests and Eggs*
BILLINGHURST, P. J. *Beasts.*
TINN FRANK. *Eggs and Nests of British Birds*
BATTEN, H. MORTIMER. *Our Garden Birds*
DALGLISH, E. FITCH *Name this Bird*
COWARD, T. A. *Birds of the British Isles and their Eggs* 3 vols
JENKINS, J. TRAVIS. *Fishes of the British Isles.*
COWARD, T. A. *Life of the Wayside and Woodland* 2 vols
STEP, E. *Animal life of the British Isles.*
BOULENGER, E. G. *Zoo Cavalcade.*
The Aquarium Book.
London Zoo.

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